AN INVENTORY OF THE HERPETOFAUNA OF VALLEY FORGE NATIONAL HISTORICAL PARK

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Technical Report NPS/PHSO/NRTR-03/088

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June 2003

NPS Cooperative Agreement
4000-9-9016

National Park Service
Northeast Region
Natural Resource Stewardship and Science
200 Chestnut Street
Philadelphia, PA 19106-2878

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Summary

An inventory of amphibians and reptiles at Valley Forge National Historical Park (VAFO) was conducted from September through November 1999, February through November 2000, March through November 2001, and February 2002. Seven standardized surveying methods were employed: coverboards, drift fence arrays, natural substrate surveys of forest and of runs (small streams), aquatic trapping, basking turtle surveys, and anura calling surveys. These methods were used to sample seven habitat types: upland forest (> 61 m [200 ft] elevation), lowland forest (< 61 m [200 ft] elevation), tall grass meadow, wetlands, runs, Valley Creek, and the Schuylkill River. In addition, opportunistic and planned general herpetological collecting were used to survey these and other accessible habitat types in the park.

Twenty-nine species were encountered at VAFO, representing 52% of the 56 potential species that could occur in the park, based on previous reports and published range maps. The species documented included seven salamanders, eight frogs and toads, six turtles, and eight snakes. None of the three species of lizard potentially present was found. Six new species for the park were recorded during the current inventory: eastern newt (*Notophthalmus viridescens*), common map turtle (*Graptemys geographica*), common musk turtle (*Sternotherus odoratus*), northern black racer (*Coluber constrictor constrictor*), northern brown snake (*Storeria dekayi dekayi*), and queen snake (*Regina septemvittata*).

The most successful surveying method was general herpetological collecting, which detected 27 of the 29 species (93%). Relatively unsuccessful methods included aquatic trapping, which yielded only three species, and drift fence arrays, which yielded eight species. These eight species were also detected by other methods that required less labor and materials. In terms of the number of species detected per person-hour spent conducting surveys, the most efficient methods were basking turtle surveys (4.4 person-hours per species) and planned general herpetological collecting (5.7 person-hours per species). The least efficient were drift fences and natural substrate surveys of runs (91.8 and 56.0 person-hours per species, respectively).

Two habitat types, wetlands and lowland forest, together supported over two-thirds of the reptile and amphibian species found at VAFO. These two habitat types occur interspersed together along the northern floodplain of the Schuylkill River, producing what can be considered the herpetofauna "hot spot" of VAFO. However, all seven habitat types subjected to standardized surveys were found to be necessary to support all of the species found in the park.

It is recommended that four surveying methods be employed in an integrated long-term monitoring program: coverboards (targeting terrestrial salamanders and other terrestrial amphibians and reptiles), anura calling surveys (frogs and toads), streamside salamander surveys (aquatic salamanders), and basking turtle surveys (aquatic turtles, snakes). One sensitive species that merits long-term monitoring, the queen snake, will be detected best by the basking turtle surveys.

The inventory identified eight species with extremely restricted geographic ranges in the park and/or that occurred at very low density. For seven of these species, specific management practices are recommended that could potentially be of benefit. In addition, several general

management practices are recommended that could be employed to maintain or enhance the overall biodiversity of the herpetofaunal community of VAFO: 1) continue to preserve forested areas with the oldest trees, 2) allow natural structure to accumulate in lotic (flowing freshwater) systems, to the extent this does not contribute to bank destabilization, 3) provide nesting sites for turtles that are protected from disturbance by visitors and predators, 4) control the invasive Japanese stilt grass (*Microstegium vimineum*), especially around the scree slopes of Mount Misery and Mount Joy, to the extent consistent with VAFO policies on herbicide usage, 5) enhance protection of the wetland/lowland forest habitat complex north of the river (referred to as the herpetofauna hot spot), and 6) increase efforts to educate visitors about park regulations that protect its natural resources. Finally, two reptile species are identified that could serve as suitable candidates for a species restoration program: the northern fence lizard (*Sceloporus undulatus hyacinthinus*) and the black rat snake (*Elaphe obsoleta obsoleta*).

Acknowledgments

Funding for this project was provided by the National Park Service and West Chester University (WCU). The following NPS personnel are thanked for their contributions: M. Carfioli, K. Heister, J. Karish, B. Lambert, and B. Rosoff. L. Rupp and B. Slocumb are thanked for their assistance with data management. Over 50 WCU students and community volunteers assisted in all aspects of the project. Of these, T. Bickhart, D. Koronkiewicz, F. Lutcher, M. Myers, and C. Wentworth are especially thanked.

Introduction

Status of Natural Resource Data Sets in 1999

The full study plan for this herpetofauna inventory was written in 1999. At that time, according to the most recent Natural Resources Status report at Valley Forge National Historical Park (VAFO; for definitions for this and other acronyms and terms, see the Appendix), four of the 12 basic data sets the park needed had been collected at Level I , but none had met the standard for Level II. Of the biological resources, birds and plants had met Level I. In addition, inventory and monitoring of several other biological resources were currently in progress as follows. In 1996, a very limited inventory and monitoring of the herpetofauna in upland forested habitats at VAFO was begun (Lutcher 1996; Carfioli 1998, 2000; and Carfioli et al. 2000). Dr. Richard Yahner of The Pennsylvania State University (PSU) tested several protocols for herpetofauna and small mammal inventorying at VAFO (Yahner et al. 1995a), and he had submitted the full study plan to inventory birds and had begun that project. Dr. Walter Tzilkowski of PSU has been studying white-tailed deer (*Odocoileus virginianus*) in the park. In 1984, Brian Cypher of PSU conducted a limited faunal inventory that covered about 10% of the park (Cypher et al. 1985b). Plant community composition of the tall grass meadows and vegetation within deer exclosures were also being investigated, and the NPS was currently conducting a Level-1 vegetation cover-type mapping project. PSU was conducting a long-term air quality monitoring program within the park, and VAFO had its own long-term water quality monitoring program. T. W. Bowersox and D. S. Larrick (PSU) had studied the requirements for conducting a long-term monitoring program of vegetation in the forested ecosystems (Bowersox and Larrick 1999).

Five Project Statements (PS) of the most recent resource management plan called for a comprehensive amphibian and reptile inventory: PS # VAFO-N-006.000 requested systematic monitoring of wildlife populations, and PS #VAFO-N-006.002 stated the need for a basic faunal inventory of the park. Especially relevant, PS #VAFO-N-006.005 and PS #VAFO-N-006.006 specifically ask that reptiles and amphibians to be inventoried and monitored, respectively. Finally, PS #VAFO-N-014.001 indicated the necessity of an inventory of biological resources in order to determine number, frequency, and distribution of rare and endangered species in the park.

Project Goals

This inventory project was intended to meet the objectives of the above Project Statements with respect to the herpetofauna at VAFO and also to determine the conservation value at VAFO in terms of supporting a diverse herpetofauna community. Accordingly, the inventory was designed to achieve the following three goals.

1. Compile a predicted species list for VAFO based on historical sightings and predicted occurrences derived from existing literature on the herpetofauna of southeastern Pennsylvania.

2. Conduct an inventory program that uses eight survey methods to document the presence/absence, distribution, and relative abundance of the herpetofauna at VAFO for each of

seven major habitat types (with special attention to state listed, federally listed, and exotic species).

3. Develop recommendations for a long-term monitoring program for herpetofauna tailored to the specific threats and resource issues at VAFO.

Methods

Study Area

Information on the study area comes primarily from Cypher et al. (1985a, 1985b) and Lundgren et al. (2002). VAFO is located 20 km northwest of Philadelphia, PA, on the border of Chester and Montgomery Counties. VAFO encompasses 1400 ha, containing open fields (600 ha), deciduous forest (440 ha), wetlands (40 ha), roads, buildings, rivers and streams (120 ha), and inholdings (200 ha). Approximately 3.2 km of Valley Creek and 5.6 km of the Schuylkill River run through the park. The open fields consist of grasslands that are mowed regularly during the growing season and tall grass meadows that are only mowed once per year. The tall grass meadows are characterized by the predominance of herbaceous graminoid species and virtual lack of woody species. Typical dominant grasses include red fescue (*Festuca rubra*), knotroot-foxtail grass (*Setaria geniculata*), panic-grass (*Panicum anceps*), broom-sedge (*Andropogon virginicus*), redtop (*Agrostis gigantea*), tall fescue (*Festuca elatior*), orchard-grass (*Dactylis glomerata*), and purpletop (*Tridens flavus*). Typical vines include Japanese honeysuckle (*Lonicera japonica*), wild grapes (*Vitis spp.*), oriental bittersweet (*Celastrus orbiculatus*), and poison ivy (*Toxicodendron radicans*). Typical woody species are apple (*Malus sylvestris*), multiflora rose (*Rosa multiflora*), and dewberry (*Rubus sp.*). The forested areas include upland forest (consisting primarily of northern red oak [*Quercus rubra*], sassafras [*Sassafras albidum*], yellow poplar [*Liriodendron tulipifera*], red maple [*Acer rubrum*], chestnut oak [*Quercus prinus*], maple leaf viburnum [*Viburnum acerifolium*] and mountain laurel [*Kalmia latifolia*]) and lowland forest (consisting primarily of red maple, flowering dogwood [*Cornus florida*], yellow poplar, sassafras, and Allegheny blackberry [*Rubus allegheniensis*]). The wetlands include vernal pools and seasonal wetlands, located primarily in the floodplains of Valley Creek and the Schuylkill River, and one semi-permanent pond north of the river. Five runs flow into the river and two flow into the creek. The park is surrounded by industrial, commercial, and residential development, as well as major highways to the north, south, and east. Regional temperatures average 0 ˚C in winter and 23 ˚C in summer, with extremes of -27 ˚C to 44 ˚C. Mean annual rainfall is 117 cm, and mean annual snowfall is 76 cm.. Soils are typically deep, well to moderately drained silt-loams. Elevation in the park ranges from a low of 18 m at the west end of Catfish Island in the Schuylkill River to 161 m on Mount Misery (Liza Rupp, VAFO GIS Coordinator, pers. comm.).

Predicted Species List: Documented and Potential Species

The predicted list for VAFO (Table 1) includes a total of 56 species that could possibly be found in the park. The list includes species that historically had been found at VAFO (Lutcher 1996; Carfioli 1998, 2000; McKeever 1982; Cypher et al. 1985b; and Yahner 1999) and species predicted to occur at VAFO based on range maps (McCoy 1982; Shaffer 1991; Behler and King 1996; Conant and Collins 1998; Petranka 1998; and Hulse et al. 2001).

Sampling Design

In consultation with VAFO natural resource managers, seven habitat types were selected for standardized surveying during the inventory. These types were based on aerial photographs, GIS

Table 1. List of reptile and amphibian species documented and predicted to occur at Valley Forge National Historical Park. Species not documented are predicted based on range maps in McCoy (1982), Shaffer (1991), Behler and King (1996), Conant and Collins (1998), Petranka (1998), and Hulse et al. (2001).

Group	Common Name	Scientific Name	ITIS TSN [1]	Source of documentation for species presence					Legal Status [7]
				Lutcher 1996 [2]	Carfioli 1997 [3]	McKeever 1982 [4]	Cypher 1985 [5]	Yahner 1999 [6]	
Salamanders									
	Eastern (Red-spotted) Newt	*Notophthalmus viridescens viridescens*	173616						
	Four-toed Salamander	*Hemidactylium scutatum*	173678						
	Jefferson Salamander	*Ambystoma jeffersonianum*	173598						
	Longtail Salamander	*Eurycea longicauda longicauda*	208310			X			
	Marbled Salamander	*Ambystoma opacum*	173591						
	Mudpuppy	*Necturus maculosus maculosus*	208249						
	Northern Dusky Salamander	*Desmognathus fuscus fuscus*	173634			X			
	Northern Red Salamander	*Pseudotriton ruber ruber*	173681	X		X			
	Northern Spring Salamander	*Gyrinophilus porphyriticus porphyriticus*	208355						
	Northern Two-lined Salamander	*Eurycea bislineata*	173685	X	X	X			
	Red-backed Salamander	*Plethodon cinereus*	173649	X	X	X		X	
	Slimy Salamander	*Plethodon glutinosus*	173650	X					
	Spotted Salamander	*Ambystoma maculatum*	173590						
Toads and Frogs									
	Bullfrog	*Rana catesbeiana*	173441			X	X		
	Eastern American Toad	*Bufo americanus americanus*	173474	X	X	X	X	X	
	Eastern Gray Treefrog	*Hyla versicolor*	173503	X		X		X	
	Eastern Spadefoot Toad	*Scaphiopus holbrooki holbrooki*	173427				X		
	Fowler's Toad	*Bufo fowleri*	173478			X	X		
	New Jersey Chorus Frog	*Pseudacris triseriata kalmi*	173526						PE
	Northern Cricket Frog	*Acris crepitans crepitans*	173521						
	Northern Green Frog	*Rana clamitans melanota*	173439			X		X	
	Northern Leopard Frog	*Rana pipiens*	173443					X	
	Northern Spring Peeper	*Pseudacris crucifer crucifer*	207304			X		X	
	Pickerel Frog	*Rana palustris*	173435	X	X	X	X	X	
	Southern (Coastal Plain) Leopard Frog	*Rana sphenocephala utricularia*	586364						PE
	Upland Chorus Frog	*Pseudacris triseriata feriarum*	173527						
	Wood Frog	*Rana sylvatica*	173440				X	X	

Table 1 (continued). List of reptile and amphibian species documented and predicted to occur at Valley Forge National Historical Park. Species not documented are predicted based on range maps in McCoy (1982), Shaffer (1991), Behler and King (1996), Conant and Collins (1998), Petranka (1998), and Hulse et al. (2001).

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Turtles									
	Bog Turtle	*Clemmys muhlenbergii*	173773						FT, PE
	Common Map Turtle	*Graptemys geographica*	173794						
	Common Musk Turtle	*Sternotherus odoratus*	173758						
	Common Snapping Turtle	*Chelydra serpentina serpentina*	173753			X	X		
	Eastern Box Turtle	*Terrapene carolina carolina*	173777	X		X	X	X	
	Eastern Mud Turtle	*Kinosternon subrubrum subrubrum*	173764						EXP
	Eastern Painted Turtle	*Chrysemys picta picta*	173784			X	X	X	
	Red-bellied Turtle	*Pseudemys rubriventris*	173814			X	X		PT
	Red-eared Slider	*Trachemys scripta elegans*	173823			X			
	Spotted Turtle	*Clemmys guttata*	173771			X			
	Wood Turtle	*Clemmys insculpta*	173772						
Lizards									
	Broadhead Skink	*Eumeces laticeps*	173961						PC
	Five-lined Skink	*Eumeces fasciatus*	173959						
	Northern Fence Lizard	*Sceloporus undulatus hyacinthinus*	173866						

Table 1 (continued). List of reptile and amphibian species documented and predicted to occur at Valley Forge National Historical Park. Species not documented are predicted based on range maps in McCoy (1982), Shaffer (1991), Behler and King (1996), Conant and Collins (1998), Petranka (1998), and Hulse et al. (2001)

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Snakes									
	Black Rat Snake	*Elaphe obsoleta obsoleta*	174178				X		
	Common Garter Snake	*Thamnophis sirtalis sirtalis*	174137	X	X	X	X	X	
	Eastern Earth Snake	*Virginia valeriae valeriae*	174152						
	Eastern Hognose Snake	*Heterodon platirhinos*	563935						
	Eastern Milk Snake	*Lampropeltis triangulum triangulum*	209242			X		X	
	Eastern Ribbon Snake	*Thamnophis sauritus sauritus*	174135						
	Eastern Worm Snake	*Carphophis amoenus amoenus*	174162						
	Northern Black Racer	*Coluber constrictor constrictor*	174170						
	Northern Brown Snake	*Storeria dekayi dekayi*	174130						
	Northern Copperhead	*Agkistrodon contortrix mokasen*	174297		X	X			
	Northern Redbelly Snake	*Storeria occipitomaculata occipitomaculata*	174132						
	Northern Ringneck Snake	*Diadophis punctatus edwardsii*	209171	X	X	X			
	Northern Water Snake	*Nerodia sipedon sipedon*	174253			X			
	Queen Snake	*Regina septemvittata*	174125						
	Rough Green Snake	*Opheodrys aestivus*	174172						PT

(1) Integrated Taxonomic Information System - Taxonomic Serial Number (from http://www.itis.usda.gov/)
(2) Coverboards deployed in 1996 (Lutcher 1996)
(3) Coverboards deployed in 1997 (Carfioli 1998, 2000)
(4) Herpetofauna species reported as seen in VAFO in 1978 and 1979, according to the McKeever Report (1982) supplied by Brian Lambert. This is the source of most VAFO Wildlife Observation Cards (WOCs).
(5) Reported as seen in Cypher et al. (1985b) flora and fauna survey for the proposed Pawling Recreation Area
(6) Reported in Yahner (1999) Technical Report NPS/PHSO/NRTR-99/076 as being detected with tested protocol
(7) Legal Status: FT = Federally Threatened, PC = PA Candidate, PE = PA Endangered, PT = PA Threatened, EXP = believed extirpated in PA as reported in Wild Resource Conservation Fund (1995)

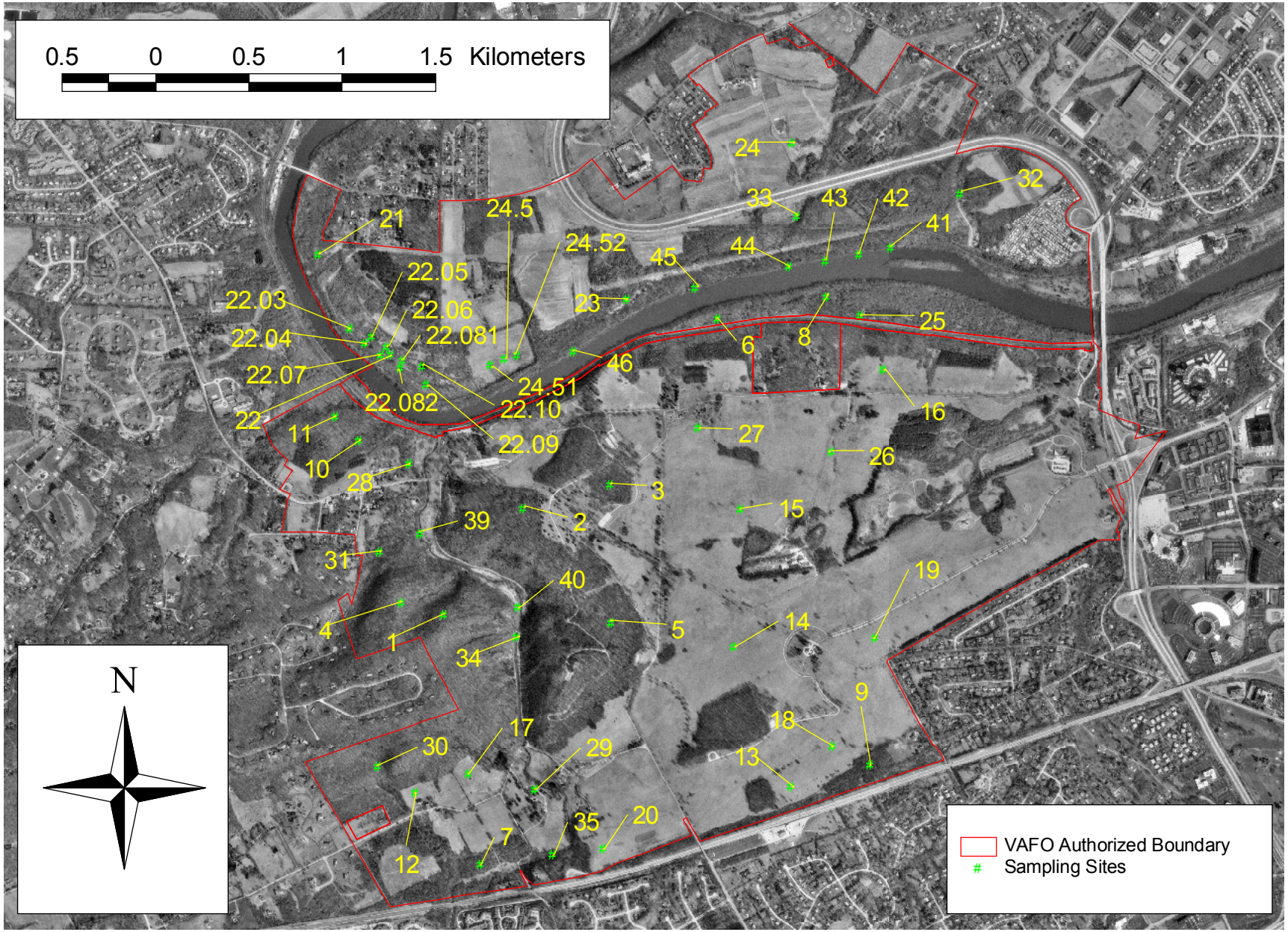
data layers used by the park, and a surface water resources map compiled by Janice DeNito of VAFO Park natural resource management: upland forest (above 61 m [200'] elevation), lowland forest (below 61 m [200'] elevation), tall grass meadows (only mowed once per year), lentic systems (wetlands, ponds, and vernal pools), and three distinct lotic systems (runs [small streams], Valley Creek, and the Schuylkill River). Omitted from the standardized survey sampling were buildings, roads, parking lots, public picnic areas, monuments, and fields mowed more than once per year. However, during the course of the inventory, animals were also found in areas categorized as three additional habitat types: road (paved or unpaved), railroad bed, and developed (inside buildings or on adjacent grounds). For convenience, the former group of seven habitat types is referred to as natural, the latter group of three as anthropogenic.

After stratifying the park into the seven habitat types as described above, sampling sites for each of seven standardized survey methods were selected so that the number of sites for each habitat type was approximately proportional to its representation in the park. Within each terrestrial habitat type (upland forest, lowland forest, and tall grass meadow), a 100-m x 100-m grid was aligned with the existing Universal Transverse Mercator (UTM) map, and all grid intersections were considered potential sampling points. From this pool of potential sites, points were eliminated if they fell within restricted zones or occurred on inaccessible slopes. Points were also eliminated if they were located within 30 m of roads, trails, parking lots, major monuments, areas with heavy visitor traffic, or park boundaries. These latter restrictions were required to minimize the aesthetic impact of sampling units on the park scenery, and reduce the probability that sampling units would be disturbed by park visitors or residential neighbors, as suggested by previous research with coverboards at VAFO (Lutcher 1996; Carfioli 1998, 2000; Carfioli et al. 2000). The remaining points in the pool for each habitat type were ranked with a computerized random number generator and then assigned to the appropriate sampling methods, with the constraint that any two sampling points had to be more than 100 m apart. Sampling points in aquatic habitats were selected on a basis of water regime, accessibility, and substrate characteristics. For sampling methods that used transects, these points were considered the starting point for the transect, with the transect direction randomly chosen from the eight ordinal bearings and adjusted as needed to meet the above criteria for starting points (e.g., cannot run through restricted zones, inaccessible slopes, etc.). For all habitat types combined, a total of 55 sampling sites was designated (Figure 1), with each site being used for one or two different standardized surveying methods. Table 2 contains a listing of all sites along with their habitat type, survey methods used, GPS heights, and GPS UTM coordinates.

Surveying Methods

Each of the seven habitat types in VAFO was surveyed using the method known as general herpetological collecting (Campbell and Christman 1982, see method 1 below) along with various combinations of seven standardized methods (see methods 2-8 below). This experimental design was intended to generate statistically robust estimates of relative abundance for the more commonly encountered species, and the most complete estimate of total species richness (total number of species present at VAFO), including even the most secretive or rare species.

Figure 1. Locations of the 55 sampling sites for the herpetofauna inventory in Valley Forge National Historical Park, 1999-2001.


0.5 0 0.5 1 1.5 Kilometers
N
VAFO Authorized Boundary
Sampling Sites
24
32
33
43
42
41
21
24.5
24.52
45
44
22.05
22.03
22.06
23
25
22.04
22.081
6
8
22.07
46
24.51
16
22.082
22.10
22
27
11
22.09
26
10
28
3
15
39
2
31
40
19
4
5
14
1
34
9
18
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29
13
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35
20
12

Table 2. Attributes of the sampling sites used for standardized survey methods. See Figure 1 for a map of site locations and Table 4 for dates and times of surveys.

Site Number	Habitat Type[1]	Census Methods[2]	Site Name	GPS Location	GPS Height (m)	UTM X Coordinate	UTM Y Coordinate
1	UF	CB, NSSF	Misery Boards	transect center	119.720	460675.03372	4438233.25469
2	UF	CB, NSSF	Joy Boards	transect center	96.333	461102.09676	4438801.53256
3	UF	CB, NSSF	Redoubt 4 Boards	transect center	78.424	461568.38940	4438927.88800
4	UF	DF	Misery Fence	array center	120.313	460448.67615	4438296.61004
5	UF	DF	Joy Fence	array center	89.088	461571.22048	4438188.49897
6	LF	CB, NSSF	River Boards W	transect center	28.035	462142.99712	4439815.86512
7	LF	CB, NSSF	Lafayette Boards	transect center	45.401	460873.99691	4436897.52468
8	LF	CB, NSSF	River Boards E	transect center	NA	462724.61608	4439932.09593
9	LF	CB, NSSF	Thomas Rd Boards	transect center	49.588	462960.55183	4437427.57818
10	LF	DF	Von Steuben Fence S	array center	40.426	460223.52060	4439162.33340
11	LF	DF	Von Steuben Fence N	array center	41.436	460092.95695	4439289.97828
12	TGM	CB	Stirling's Boards	transect center	74.101	460521.66309	4437283.28244
13	TGM	CB	Field 57 Boards	transect center	NA	462538.02509	4437314.43110
14	TGM	CB	Artillery Park Boards	transect center	53.733	462229.73791	4438062.29602
15	TGM	CB	Grand Parade Boards	transect center	49.197	462265.07609	4438798.58369
16	TGM	CB	Chapel Lot Boards	transect center	54.896	463027.71022	4439543.75417
17	TGM	DF	Covered Bridge Fence	array center	64.558	460811.83557	4437382.14412
18	TGM	DF	Field 57 Fence	array center	NA	462757.25570	4437530.22749
19	TGM	DF	Glover Fence	array center	NA	462987.50064	4438109.98686
20	TGM	DF	Knox's Fence	array center	60.264	461530.79739	4436982.81459
21	WET	ACS	Pond 1	listening station	24.180	460002.94640	4440159.22022
22	WET	ACS	Desilting Basins	listening station	25.801	460389.59019	4439624.93625
22.03	WET	BTS	Pond 3	center pond 3	NA	460175.96343	4439757.93662
22.04	WET	AT, BTS	Pond 4	center pond 4	NA	460255.51176	4439680.01173
22.05	WET	BTS	Pond 5	center pond 5	NA	460287.98046	4439717.35074
22.06	WET	AT, BTS	Pond 6	center pond 6	NA	460369.15223	4439660.53050
22.07	WET	AT, BTS	Pond 7	center pond 7	NA	460339.93040	4439619.94462
22.081	WET	BTS	Pond 8N	center pond 8N	NA	460453.57087	4439592.34622
22.082	WET	BTS	Pond 8S	center pond 8S	NA	460442.20682	4439546.89003
22.09	WET	BTS	Pond 9	center pond 9	NA	460583.44570	4439465.71826
22.10	WET	BTS	Pond 10	center pond 10	NA	460560.71760	4439559.87751

Table 2 (continued). Attributes of the sampling sites used for standardized survey methods. See Figure 1 for a map of site locations and Table 4 for dates and times of surveys.

Site Number	Habitat Type[1]	Census Methods[2]	Site Name	GPS Location	GPS Height (m)	UTM X Coordinate	UTM Y Coordinate
23	WET	ACS	Superintendent's Trail	listening station	23.047	461655.60329	4439919.13373
24	WET	ACS, AT	Fatlands Pond	center of pond	NA	462543.94541	4440752.74422
24.50	WET	ACS	Walnut Hill Ponds	between ponds	21.985	461000.70951	4439594.77004
24.51	WET	BTS	Walnut Hill Ponds	center west pond	NA	460926.89184	4439564.16562
24.52	WET	BTS	Walnut Hill Ponds	center east pond	NA	461067.33579	4439616.83210
25	WET	ACS	South Floodplain	listening station	31.871	462905.58915	4439830.45410
26	WET	ACS	Nature Center	listening station	43.116	462751.03497	4439104.19654
27	WET	ACS	Varnum's Quarters	listening station	NA	462039.05517	4439233.06955
28	WET	ACS	McIntosh	listening station	29.005	460490.15320	4439039.73448
29	WET	ACS	Knox Estate Pools	listening station	32.793	461164.08051	4437296.13792
30	RUN	NSSR	Stirling's Run	transect center	NA	460323.55049	4437423.72769
31	RUN	NSSR	Fisher's Run	transect center	NA	460331.03716	4438568.35903
32	RUN	NSSR	Lamb Run	transect center	NA	463444.35472	4440478.96598
33	RUN	NSSR	Myer's Run	transect center	NA	462568.96166	4440356.60606
34	CRK	AT	Valley Creek 34	trapping station	NA	461065.06986	4438115.26684
35	CRK	AT	Valley Creek 35	trapping station	NA	461258.45548	4436951.88285
39	CRK	AT	Valley Creek 39	trapping station	NA	460550.51934	4438664.64504
40	CRK	AT	Valley Creek 40	trapping station	NA	461072.65739	4438271.71916
41	RIV	AT	River 41	trapping station	NA	463069.19623	4440194.76873
42	RIV	AT	River 42	trapping station	NA	462902.61690	4440156.66005
43	RIV	AT	River 43	trapping station	NA	462720.09006	4440122.99298
44	RIV	AT	River 44	trapping station	NA	462524.83317	4440092.69384
45	RIV	AT	River 45	trapping station	NA	462021.27352	4439977.72648
46	RIV	AT	River 46	trapping station	NA	461371.03774	4439637.52903

(1) CRK = Valley Creek, LF = lowland forest, RIV = Schuylkill River, RUN = runs (small streams), TGM = tall grass meadow, UF = upland forest, WET = wetland.

(2) CB = coverboard, NSSF = natural substrate survey in forest, DF = drift fence, ACS = anura calling survey, BTS = basking turtle survey, AT = aquatic trapping.

The survey methods were chosen to balance their efficacy, cost, and ease of use (Simons 1995). Most of the methods are described in more detail in Yahner et al. (1995b) and Seigel and Doody (1996). See Table 3 for the species each method was potentially able to detect.

Because the natural resource managers at VAFO are especially interested in the population of eastern box turtles (*Terrapene carolina carolina*) within the park (K. Heister, pers. comm.), members of this species were individually marked using standard approved carapace notching identification codes (ASIH 1987; see Tiebout 2003 for actual codes used). Other herpetofaunal species were not marked.

A complete description of the field procedures for each method, including equipment lists, data forms, and data codes are provided in the companion Herpetofauna Survey Handbook (Tiebout 2003). The actual dates and times of each survey are given in Table 4.

1. General herpetological collecting (GHC) -- This method typically consists of (a) traveling an area on foot to observe animals that are visible aboveground, (b) turning and replacing cover objects, (c) searching in and around burrows, crevices, hollow logs, and other refugia, (d) nighttime road-surveys, (e) seining, dipnetting, and electro-shocking small bodies of water, and (f) spot-light surveys of aquatic habitats. General herpetological collecting is not constrained to standardized times or transects, but instead relies upon the past experiences and professional judgment of the investigator. Materials required include general collecting equipment (tongs, stump rippers, potato rakes, dipnets, field guides, etc.) for surveying in all habitat types. Locations of all animals detected during general herpetological collecting were recorded by one of three methods: GPSed in the field, marked on an aerial photograph and later digitized into GIS, or referenced with landmarks (e.g., east shore of Valley Creek, 20 m north of the foot bridge) and later digitized into GIS.

General herpetological collecting was conducted in two ways. Opportunistic general herpetological collecting was employed while conducting other scheduled activities (such as one of the standard survey methods, travelling among sites, setting up traps, etc.). Planned general herpetological collecting was conducted in discrete time blocks. Planned general herpetological collecting was used to cover areas of the park not included in the standardized sampling methods or to search for specific taxa from the predicted list that were not being detected by the standardized methods. Considerable opportunistic general herpetological collecting was practiced while traveling about the park and numerous planned general herpetological collecting trips were made to ensure thorough coverage of the park. Six of these planned trips were taxon-specific searches, which were conducted to follow up anecdotal reports of new species and to attempt to locate particular species likely to occur at VAFO but not detected by any of the other methods: red-bellied turtle (*Pseudemys rubriventris*), northern redbelly snake (*Storeria occipitomaculata occipitomaculata*), black rat snake, rough green snake (*Opheodrys aestivus*), queen snake, and eastern newt.

2. Natural Substrate Surveys in Forest (NSSF) -- Each of the terrestrial habitat sampling units (three in upland forest [sites 1-3] and four in lowland forest [sites 6-9]; Figure 1) consisted of a belt transect 100-m long and 5-m wide. The entire belt transect was searched for animals by

Table 3. Species predicted to be found by each of the eight surveying methods. The predictions of which methods would find which species come from Yahner et al. (1999, Appendix 3) and from general knowledge of the behavior and habitat use of each species.

Group	Common Name	Survey Method[1]							
		GHC	NSSF	NSSR	CB	DF	ACS	BTS	AT
Salamanders									
	Eastern (Red-spotted) Newt	X	X		X	X			X
	Four-toed Salamander	X	X	X	X				
	Jefferson Salamander	X	X		X				
	Longtail Salamander	X	X	X	X				
	Marbled Salamander	X	X		X				
	Mudpuppy	X							X
	Northern Dusky Salamander	X	X	X	X				
	Northern Red Salamander	X	X	X	X				
	Northern Spring Salamander	X	X	X	X				
	Northern Two-lined Salamander	X	X	X	X				
	Red-backed Salamander	X	X	X	X				
	Slimy Salamander	X	X		X				
	Spotted Salamander	X	X		X				
Toads and Frogs									
	Bullfrog	X				X	X		X
	Eastern American Toad	X	X		X	X	X		
	Eastern Gray Treefrog	X	X		X	X	X		
	Eastern Spadefoot Toad	X	X		X	X	X		
	Fowler's Toad	X	X		X	X	X		
	New Jersey Chorus Frog	X	X		X	X	X		X
	Northern Cricket Frog	X	X		X	X	X		X
	Northern Green Frog	X				X	X		X
	Northern Leopard Frog	X				X	X		X
	Northern Spring Peeper	X	X		X	X	X		
	Pickerel Frog	X	X		X	X	X		X
	Southern (Coastal Plain) Leopard	X				X	X		X
	Upland Chorus Frog	X	X		X	X	X		X
	Wood Frog	X	X		X	X	X		
Turtles									
	Bog Turtle	X						X	X
	Common Map Turtle	X				X		X	X
	Common Musk Turtle	X	X		X	X		X	X
	Common Snapping Turtle	X				X		X	X
	Eastern Box Turtle	X	X		X	X			
	Eastern Mud Turtle	X	X		X	X		X	X
	Eastern Painted Turtle	X				X		X	X
	Red-bellied Turtle	X				X		X	X
	Red-eared Slider	X				X		X	X
	Spotted Turtle	X				X		X	X
	Wood Turtle	X	X		X	X		X	

Table 3 (continued). Species predicted to be found by each of the eight surveying methods. The predictions of which methods would find which species come from Yahner et al. (1999, Appendix 3) and from general knowledge of the behavior and habitat use of each species.

Group	Common Name	Survey Method[1]							
		GHC	NSSF	NSSR	CB	DF	ACS	BTS	AT
Lizards									
	Broadhead Skink	X	X		X	X			
	Five-lined Skink	X	X		X	X			
	Northern Fence Lizard	X	X		X	X			
Snakes									
	Black Rat Snake	X	X		X	X			
	Common Garter Snake	X	X		X	X			
	Eastern Earth Snake	X	X		X	X			
	Eastern Hognose Snake	X	X		X	X			
	Eastern Milk Snake	X	X		X	X			
	Eastern Ribbon Snake	X	X		X	X		X	X
	Eastern Worm Snake	X	X		X	X			
	Northern Black Racer	X	X		X	X			
	Northern Brown Snake	X	X		X	X			
	Northern Copperhead	X	X		X	X			
	Northern Redbelly Snake	X	X		X	X			
	Northern Ringneck Snake	X	X		X	X			
	Northern Water Snake	X	X	X	X	X		X	X
	Queen Snake	X	X	X	X	X		X	X
	Rough Green Snake	X	X		X	X			

(1) GHC = general herpetological collecting , NSSF = natural substrate survey in forest, NSSR = natural substrate survey in run , CB = coverboard, DF = drift fence, ACS = anura calling survey, BTS = basking turtle survey, AT = aquatic trapping.

Table 4a. Dates and times of Anura Calling Surveys. Several surveys lasted past midnight and hence span two dates.

Survey No.	Date	Time Start	Time End
1	11-Mar-00	18:35	21:55
2	20-May-00	20:57	0:00
2	21-May-00	0:00	1:00
3	28-Jun-00	21:08	0:00
3	29-Jun-00	0:00	2:19
4	10-Mar-01	18:28	22:33
5	22-Mar-01	18:57	22:30
6	24-May-01	20:56	23:45
7	5-Jul-01	21:39	12:00
7	6-Jul-01	0:00	1:24

Table 4b. Dates and times of Basking Turtle Surveys.

Survey No. [1]	Date	Time Start	Time End
B-1	31-May-00	10:30	14:19
C-1	7-Sep-00	9:32	13:50
RN-1	26-Apr-01	10:20	14:00
RS-1	27-Apr-01	10:00	12:25
B-2	1-Jun-00	11:00	13:42
C-2	5-Apr-01	11:00	12:30
RN-2	30-Jun-01	8:00	9:48
RS-2	24-Aug-01	11:15	13:08
B-3	5-Apr-01	13:20	13:50
C-3	19-Jul-01	9:50	12:20

(1) Survey No. codes:

B-1 = Desilting Basins, first survey
C-1 = Valley Creek, first survey
RN-1 = Schuylkill River, north bank, first survey
RS-1 = Schuylkill River, south bank, first survey
B-2 = Desilting Basins, second survey
C-2 = Valley Creek, second survey
RN-2 = Schuylkill River, north bank, second survey
RS-2 = Schuylkill River, south bank, second survey
B-3 = Desilting Basins, third survey
C-3 = Valley Creek, third survey

Table 4c. Dates and times of Coverboard Surveys and concurrent Natural Substrate Surveys of Forest. Some surveys required more than one day to complete.

Survey No.	Date	Time Start	Time End
1	18-Sep-99	12:44	17:32
1	19-Sep-99	9:32	17:22
2	15-Oct-99	9:15	14:45
2	17-Oct-99	9:44	16:24
3	18-Mar-00	9:23	17:30
3	19-Mar-00	10:53	15:53
4	9-May-00	9:10	17:18
5	29-Jun-00	12:40	16:42
5	30-Jun-00	9:20	11:58
6	29-Jul-00	8:11	13:40
6	30-Jul-00	8:11	10:57
7	30-Sep-00	9:30	15:02
7	1-Oct-00	9:35	15:33
8	8-May-01	9:27	14:47
8	11-May-01	9:21	14:03
9	16-Aug-01	8:26	16:43

Table 4d. Dates and times of Aquatic Trapping Surveys. Each trap was opened and closed at approximately the same time of day so that each trap was open about 48 hours per survey.

Survey No.[1]	Date Open	Time Open	Date Close	Time Close
B-1	14-Jun-00	10:53	16-Jun-00	11:55
R-1	13-Jun-01	13:00	15-Jun-01	11:16
C-1	20-Jun-01	13:48	22-Jun-01	10:42
R-2	7-Aug-01	10:36	9-Aug-01	11:05
C-2	23-Aug-01	10:22	25-Aug-01	10:20

(1) Survey No. codes:

B-1 = Desilting Basins, first survey
R-1 = Schuylkill River, first survey
C-1 = Valley Creek, first survey
R-2 = Schuylkill River, second survey
C-2 = Valley Creek, second survey

Table 4e. Dates and times of Planned General Herpetological Collecting Surveys.

Survey No.	Date	Time Begin	Time End
1	6-Apr-00	10:00	14:30
2	7-Apr-00	12:20	13:00
3	5-May-00	9:50	16:00
4	30-Jun-00	11:30	14:10
5	30-Jul-00	11:45	12:30
6	8-Sep-00	9:40	13:45
7	12-Apr-01	11:33	16:15
8	13-Apr-01	10:00	15:45
9	26-Apr-01	16:20	17:15
10	3-May-01	8:40	11:50
11	4-May-01	8:30	12:10
12	24-May-01	13:45	18:45
13	6-Jun-01	16:17	22:15
14	14-Jun-01	10:53	15:30
15	3-Jul-01	8:10	11:30
16	10-Jul-01	9:05	11:18
17	20-Jul-01	9:25	13:45
18	7-Aug-01	12:25	14:32
19	2-Nov-01	12:30	16:00
20	7-Nov-01	10:30	12:20
21	11-Nov-01	11:00	12:00
22	26-Feb-02	10:35	13:26

Table 4f. Dates and times of Drift Fence Surveys. Each drift fence array was opened and closed at approximately the same time of day so that each array was open about 72 hours per survey.

Survey No.	Date Open	Time Open	Date Close	Time Close
1	30-Sep-99	8:15	3-Oct-99	12:59
2	21-Oct-99	8:23	24-Oct-99	13:27
3	5-Mar-00	9:25	8-Mar-00	14:28
4	22-May-00	9:30	25-May-00	14:06
5	20-Jun-00	9:43	23-Jun-00	13:29
6	3-Aug-00	8:25	6-Aug-00	13:17
7	21-Sep-00	9:05	24-Sep-00	14:31
8	29-May-01	12:59	1-Jun-01	14:32
9	31-Jul-01	9:30	3-Aug-01	14:55

Table 4g. Dates and times of Natural Substrate Surveys of Runs. Each survey included all four sampling sites (Lamb, Myer's, Fisher's and Stirling's Runs) and required from two to four days to complete.

Survey No.	Date	Time(s)
1	9-Oct-99	AM, PM
1	10-Oct-99	PM
1	15-Oct-99	AM, PM
2	27-Nov-99	AM, PM
2	28-Nov-99	AM
3	26-Feb-00	PM
3	27-Feb-00	AM, PM
3	1-Mar-00	AM
4	18-Mar-00	AM, PM
4	19-Mar-00	AM, PM
5	16-Apr-00	AM, PM
5	25-Apr-00	AM
5	29-Apr-00	AM, PM
6	29-May-00	PM
6	3-Jun-00	AM
7	5-Jun-00	AM
7	5-Jul-00	AM
7	6-Jul-00	AM
7	8-Jul-00	AM
8	17-Jul-00	AM
8	18-Jul-00	AM, PM
8	18-Jul-00	AM
8	21-Jul-00	AM
9	1-Aug-00	AM
9	2-Aug-00	AM, PM
9	8-Aug-00	AM, PM
9	9-Aug-00	AM, PM

carefully turning and replacing all cover objects greater than 7.5-cm wide (following Yahner et al. 1995b, 1999). Terrestrial natural substrate surveys were conducted six times for the first year (1999-2000) and three times for the second year (2000-2001) for a total of nine surveys conducted in spring, summer, and fall.

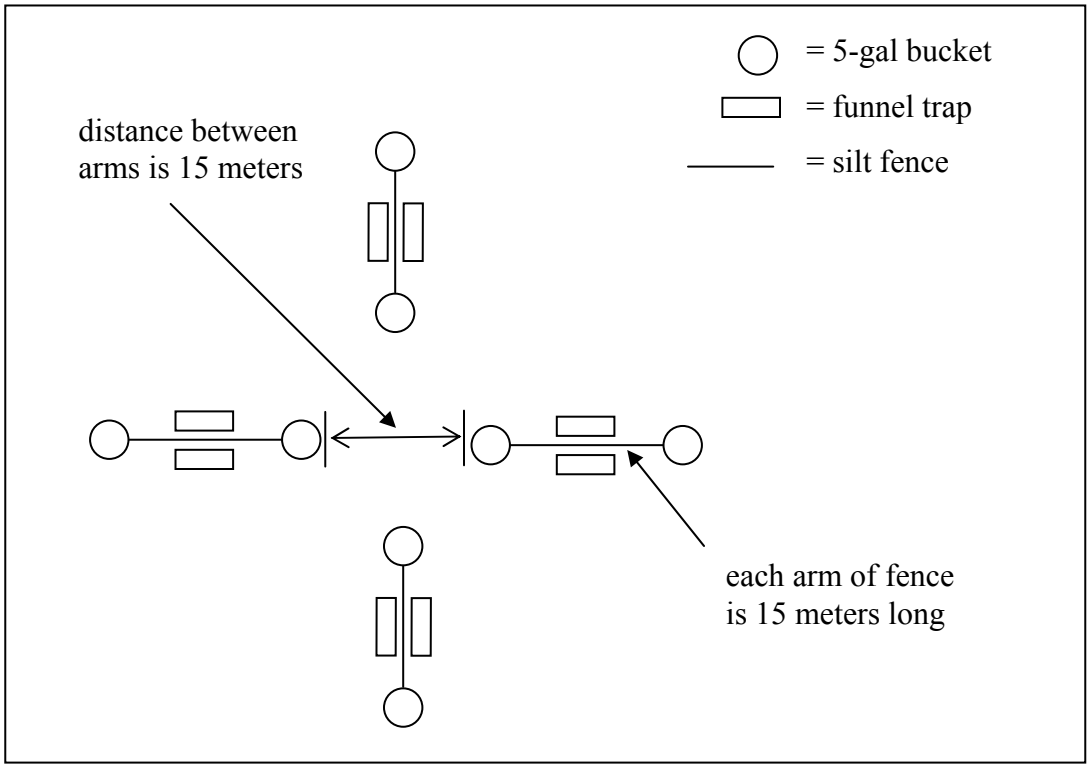
3. Natural Substrate Surveys in Runs (NSSR) -- Each of the aquatic habitat sampling sites (Stirling's Run [site 30], Fisher's Run [site 31], Lamb Run [site 32], and Myer's Run [site 33]; Figure 1) contained many more cover objects than their terrestrial counterparts. Accordingly, instead of surveying an entire 100- x 5-m belt transect, as done for the NSSF surveys, smaller sampling quadrats were established along a transect. First, an 80-m transect was established along the length of a run and stratified into eight 10-m segments. Within each 10-m segment a 2- x 5-m quadrat was randomly located, with the long axis parallel to the edge of the stream such that 1 m of the quadrat was on the water side and 1 m on the shore side. This provided equal amounts (40 m^2) of wet and dry substrate for each transect. During each survey, all cover objects greater than 7.5 cm wide were turned and animals found underneath were captured by hand or with small dipnets. All cover objects were returned to their original locations. Surveyors began each transect at the furthest downstream quadrat and surveyed moving upstream to minimize the disturbance to each quadrat prior to surveying. The aquatic natural substrate surveys were conducted nine times during the first year only (October 1999 - August 2000).

4. Coverboards (CB) -- Coverboards were deployed in triplets consisting of: one large fir CDX plywood board (61 cm x 122 cm x 1.25 cm thick [24" x 48" x 1/2" thick]), one small cypress board (20 cm x 107 cm x 2.5 cm thick [8" x 42" x 1" thick]), and one undried white oak board (30 cm x 30 cm x 2.5 cm thick [12" x 12" x 1" thick]). Design, deployment, and surveying schedule for coverboards was in accordance with the protocols developed by the Terrestrial Salamander Monitoring Program (TSMP; Droege et al. 1997). The undried white oak board is the standard recommended by the TSMP, the other two board types have been proven effective in attracting other species of herpetofauna in addition to terrestrial salamanders at VAFO (Lutcher 1996; Carfioli 1998; Carfioli 2000; Carfioli et al. 2000). All boards in a triplet were separated by 0.5 m. The sampling unit was a 100-meter transect containing 10 such triplets, with each triplet separated by 11 m, for a total of 30 boards per transect. Coverboards were placed within the belt transects described above for Natural Substrate Surveys in Forest (for forest habitats only, sites 1-3, 6-9), and 5 additional coverboard transects were established in tall grass meadows (sites 11-15), for a total of 12 coverboard transects (Figure 1).

The boards were put in the field the first week of September 1999 and were checked once per survey. Surveys were conducted six times for the first year (1999-2000) and three times for the second year (2000-2001), for a total of nine surveys conducted in spring, summer, and fall.

5. Drift Fences (DF) -- Each sampling unit was a modified Christman drift fence array (Figure 2), consisting of four 15-m lengths ("arms") of drift fence arranged in an "X" (Campbell and Christman 1982). The drift fence was constructed of 91 cm tall (36") black polypropylene silt fence (Enge 1997) supported at 2-3 m intervals with a 2.5 cm x 2.5 cm x 122 cm (1" x 1" x 48") wooden stake driven 30 cm (12") into the ground. To prevent animals from crawling under the fence, the bottom edge was attached to the ground with 15 cm (6") landscape staples placed at

Figure 2. Top view schematic of a single modified Christman drift fence array (Campbell and Christman 1982), composed of four lengths (or "arms") of drift fencing with traps.



approximately 61 cm (24”) intervals. At the end of each arm of the "X", a pitfall trap (18.9 L [5-gallon] plastic bucket) was buried flush with the surface of the ground. At the midpoint of each arm, on both sides of the fence, funnel traps (18 cm x 18 cm x 76 cm [7” x 7” x 30”] H x W x L) were set on the surface of the ground and anchored in place with a 2.5 cm x 5 cm x 61 cm (1” x 2” x 24”) pine grade stake driven 30 cm (12”) into the ground. Each pitfall trap was shaded by the lid of the bucket raised 5 cm (2”) above the ground by clothespins. Funnel traps were shaded with a folded rectangle of cardboard approximately 51 cm x 76 cm (20” x 30”). Pitfall traps contained a moist sponge to prevent over-heating and dehydration of captured animals, a small hiding container for refuge, and a wad of loose cotton for small rodents to use in nesting. The following drift fences arrays are marked on Figure 1: two in upland forest (sites 4 and 5), two in lowland forest (sites 10 and 11), and four in tall grass meadow (sites 17-20), for a total of eight arrays.

Surveys were conducted six times for the first year (1999-2000) and three times for the second year (2000-2001), for a total of nine surveys conducted in spring, summer, and fall. During a given survey, each array was open (traps set) for three days, for a total of 27 days during the two years of field work. Once the traps were set they were checked daily, and all herps captured were processed and then released 5 m from the drift fence on the side opposite their site of capture. During times of the year when the arrays were not used, the pitfall traps were covered (buckets were sealed with their lids) and the funnel traps were removed.

6. Anura (Frog and Toad) Calling Surveys (ACS) -- Ten sites at lentic systems were designated for conducting anura calling surveys (sites 21-29, 24.5; Figure 1). Each of these sites was visited three or four evenings during each spring (2000 and 2001) to determine which species of frogs and toads were heard calling. The dates were chosen to represent the first spring evenings in which maximum daytime air temperatures exceeded 7.2 °C (45°F), 12.8 °C (55°F), and 21.1 °C (70°F) (following the protocols for the Vermont Calling Frog Survey, as recommended by NAAMP (Mertz 1999)). Surveys commenced 30 minutes after sunset, and at each sampling site, observers listened for 3 minutes. Calls were identified to species, and abundance scored for each species as shown in Table 5. Each survey site covered an area approximately 500 m in radius, the distance from which calls could be reliably identified to species (Mertz 1999).

7. Basking Turtle Surveys (BTS) -- Basking turtles and other aquatic or semi-aquatic herpetofauna were visually surveyed at four locations: (a) 11 vernal ponds and desilting basins north of the Schuylkill River (in the vicinity of ACS sites 22 and 24.5), (b) the entire length of Valley Creek (both shorelines surveyed concurrently), (c) the north and (d) south shoreline of the Schuylkill River along their entire length in the park. Ten surveys were conducted on days conducive to basking by turtles, typically in early spring or early fall when water temperatures were relatively cool, and clear skies provided ample sunlight for thermoregulation. Field glasses and spotting scopes were used to scan for animals basking on the banks or on rocks, logs, and other structures emerging from the water. Animal locations were GPSed or mapped in the field for later digitizing from the maps, with the exception of animals seen in the 11 vernal ponds and desilting basins (sites 22.03, 22.04, 22.05, 22.06, 22.07, 22.081, 22.082, 22.09, 22.10, 24.51, and 24.052). These were mapped as being in the center of their respective bodies of water.

Table 5. Wisconsin Index Values, used for scoring the abundance of calling anurans during anura calling surveys (Mertz 1999).

Index Value 0	No amphibians calling.
Index Value 1	Individuals can be counted. There is space between calls.
Index Value 2	Calls of individuals can be distinguished but there is some overlapping of calls.
Index Value 3	Full chorus. Calls are constant, continuous, and overlapping.

8. Aquatic Traps (AT) -- At each trapping site three different traps were set: one unbaited minnow trap (for snakes, small amphibians and hatchling turtles) and two turtle traps (for large amphibians and turtles). One turtle trap was baited with a carnivore bait (canned sardines or tuna) and the other with an herbivore bait (canned creamed corn). The trap dimensions were approximately 23 cm x 23 cm x 41 cm (H x W x L, 9" x 9" x 16") for minnow traps and 43 cm x 43 cm x 91 cm (H x W x L, 17" x 17" x 36") for turtle traps. Traps rested on the bottom in shallow water (at least 30 cm [12"] deep) near the shoreline of permanent or semi-permanent bodies of water. Traps were set approximately 5-10 m apart and held in place with 122 cm (48") wooden stakes. During each trapping session, four sites were run concurrently for approximately 48 h, during which time they were checked once or twice per day. Two trapping sessions were conducted in Valley Creek (sites 34, 35, 39 and 40) and the Schuylkill River (sites 41-46), but only one in vernal ponds/wetlands (three at site 22 [vernal ponds 22.04, 22.06, and 22.07], one at site 24) due to dry conditions during the 2000 field season. Six sites were used in the river because during the second year two of the sites had to be moved due to a change in water level.

Weather Variables

At the beginning and end of each survey the following data were recorded: (a) Weather Bureau Sky Codes (0-8, see Table 6, (b) Beaufort Wind Scale (0-5, see Table 7, (c) air temperature in the shade at 2 meters above ground, and (d) relative humidity in the shade at 2 meters above ground. If the survey lasted more than 1 h, these data were also collected at approximately one-hour intervals throughout the survey. These data were also collected for planned general herpetological collecting.

Herpetofauna Encounters

For each herpetofauna animal encountered the following data were recorded: species, body length (snout-vent-length, or carapace length for turtles, in cm), gender (if externally identifiable), and color morph (for red-backed salamanders [*Plethodon cinereus*] only). In addition, for coverboard transects only, for each board flipped the presence or absence of ants and worms were recorded (following recommendations of Droege et al. 1997), as time allowed.

Habitat Use Analyses

Habitat use by the resident herpetofauna was assessed by calculating the number of different habitat types each species was found in and by calculating a Habitat Diversity Index (HDI) for each species using the Shannon Index (Brower et al. 1998), as follows:

Habitat Diversity Index (HDI) = $H' = - \Sigma \text{Log}_{10}(p_i)*(p_i)$

where p_i = the proportion of total sightings for a given species that occurred in habitat type i

The HDI integrates both the number of different habitat types used by a given species and the equitability of use. Thus, the highest diversity index would occur for a species that used multiple habitat types without being overly dependent on just one or two.

Table 6. Weather Bureau Sky Codes, used for scoring sky conditions for each survey (Mertz 1999).

0	Few clouds
1	Partly cloudy (scattered) or variable sky
2	Cloudy (broken) or overcast
4	Fog or smoke
5	Drizzle
7	Snow
8	Showers

Table 7. Beaufort Wind Scale Codes, used for scoring wind intensity for each survey (Mertz 1999).

Beaufort Wind Scale	Wind Speed km/h	Description
0	<1.6	Calm; smoke rises vertically
1	1.6-4.8	Light air; rising smoke drifts; weather vane inactive
2	6.4-11.3	Light breeze; leaves rustle, can feel wind on face
3	12.9-19.3	Gentle breeze; leaves and twigs move around, small flags extend
4	20.1-30.0	Moderate breeze; moves thin branches, raises loose paper
5	30.6-38.6	Fresh breeze; trees sway

Status of Detected Species

Species that were found by the inventory were categorized based on how well they had been previously documented. A given species is considered to have been a “well-known resident” at VAFO if it had already been reported in three or more of the five studies presented in the predicted list (Table 1). A species is considered "little-known" if only reported in one or two of these studies.

Status of Predicted Species Not Found

Each predicted species that was not found by the inventory was assigned to one of four residency status categories based on the presence of two or more of the following diagnostic criteria.

Possible Current Resident = this species likely occurs in the park but was not documented during the current inventory.

> Criteria: VAFO is within the current geographic range, VAFO has previous record(s) of this species in the park, VAFO contains suitable habitat to support this species

Possible Extirpated Resident = this species likely inhabited VAFO historically, but has been locally extirpated.

> Criteria: VAFO is within the current or historic geographic range, VAFO has no previous records, VAFO contains some suitable habitat, possible mechanism for extirpation has been identified.

Indeterminate = cannot determine if species ever inhabited VAFO or whether species likely currently occurs in park.

> Criteria: VAFO may or may not be in current geographic range, VAFO has no previous records, VAFO contains some suitable habitat.

Probable Nonresident = evidence suggests species does not occur in park, perhaps never occurred in park.

> Criteria: VAFO may be outside of current geographic distribution, VAFO has no previous records, VAFO contains little or no appropriate habitat.

Results

Species Detected

Seven salamander species, eight frog species, six turtle species, and eight snake species were detected, for a total of 29 amphibian and reptile species found during the two-year study (Table 8). The surveys detected none of the three species of lizards that were on the predicted species list (Table 1).

Species varied markedly in the number of survey methods that detected them (Table 8). On average, a given species was detected by 2.5 of the eight survey methods. The red-backed salamander was the most readily detected species, being found by five survey methods. Six species, representing all four of the taxonomic groups detected in this inventory, were found by only a single method. By taxonomic group, turtles were generally the least detectable, averaging 1.8 methods per species; while anurans were the most detectable, averaging 3.0 methods per species.

Individual animals were counted for all of the taxonomic groups, except for the anurans (frogs and toads) detected during nocturnal calling surveys, which were scored based on chorus intensity (Table 5). Each time an anuran species was recorded as calling at an anura calling survey site during a survey, it was recorded as one individual. Thus, the anuran encounter frequencies underestimate actual abundance. The maximum chorus intensity recorded for each anura species at each site is given in Table 9.

Of the 2397 individual encounters for all groups, the most common species was the red-backed salamander, which comprised 52.9% of all encounters. Over one-third (37.6%) of the encounters for this species were under coverboards, about one fifth (18.7%) were at drift fences, with the rest scattered among three other sampling methods. In fact, the four most abundant species were salamanders, making this taxon a major component of the herpetofauna at VAFO (74.3% of all encounters).

The survey methods varied markedly in the number of species they detected. General herpetological collecting (GHC), which entailed opportunistic and planned GHC surveys, was by far the most effective. Opportunistic and planned GHC surveys each found 24 species, for a combined total of 27 out of the 29 (93%) species found at VAFO. Several of the planned GHC surveys included taxon-specific searches (see "Sampling Design" above), which were successful in detecting two species (eastern newt and queen snake) of the six that were targeted. The second most successful method was the basking turtle surveys (yielding 11 species), followed by coverboards and drift fences (each of which yielded eight species). The drift fence surveys did not contribute any new species (i.e., not detected by at least one of the other methods) to the inventory and were the most costly in terms of materials (approx. $2000), labor to install and maintain (approx. 300 person-hours), and labor to run surveys (approx. 735 person-hours). The aquatic traps were least effective, yielding only three species.

In terms of the number of species detected per person-hour spent sampling in the field (i.e., not counting time spent installing drift fences, coverboards, etc.; Table 10), the most efficient method was the basking turtle survey, with only 4.4 person-hours expended per species detected.

Table 8. Predicted list of Valley Forge National Historical Park herpetofauna species, with number of encounters per species for each of eight survey methods used 1999-2001.

Group	Common Name	Survey Method									How Many Methods Detected Each Species
		General Herpetological Collecting (GHC)	Natural Substrate Survey in Forest (NSSF)	Natural Substrate Survey in Runs (NSSR)	Coverboards (CB)	Drift Fences (DF)	Anura Calling Surveys (ACS)	Basking Turtle Surveys (BTS)	Aquatic Trapping (AT)	ALL METHODS COMBINED	
Salamanders											
	Eastern (Red-spotted) Newt	12								12	1
	Four-toed Salamander										
	Jefferson Salamander										
	Longtail Salamander	8		2						10	2
	Marbled Salamander										
	Mudpuppy										
	Northern Dusky Salamander	4		147						151	2
	Northern Red Salamander	4		98		1				103	3
	Northern Spring Salamander										
	Northern Two-lined Salamander	12		223						235	2
	Red-backed Salamander	426	120	9	477	237				1269	5
	Slimy Salamander				1					1	1
	Spotted Salamander										
Toads and Frogs											
	Bullfrog	13					7	8	1	29	4
	Eastern American Toad	43	3		3	12	8			69	5
	Eastern Gray Treefrog	2					4	2		8	3
	Eastern Spadefoot Toad										
	Fowler's Toad	17								17	1
	New Jersey Chorus Frog										
	Northern Cricket Frog										
	Northern Green Frog	9				1	8			18	3
	Northern Leopard Frog										
	Northern Spring Peeper	6					16			22	2
	Pickerel Frog	38				1	3	2		44	4
	Southern (Coastal Plain) Leopard Frog										
	Upland Chorus Frog										
	Wood Frog	1					2			3	2

Table 8 (continued). Predicted list of Valley Forge National Historical Park herpetofauna species, with number of encounters per species for each of eight survey methods used 1999-2001.

Group	Common Name	Survey Methods									No. Methods
		GHC	NSSF	NSSR	CB	DF	ACS	BTS	AT	ALL	
Turtles											
	Bog Turtle										
	Common Map Turtle	2								2	1
	Common Musk Turtle							2	1	3	2
	Common Snapping Turtle	8						5	9	22	3
	Eastern Box Turtle	16								16	1
	Eastern Mud Turtle										
	Eastern Painted Turtle	14						30		44	2
	Red-bellied Turtle										
	Red-eared Slider	12						46		58	2
	Spotted Turtle										
	Wood Turtle										
Lizards											
	Broadhead Skink										
	Five-lined Skink										
	Northern Fence Lizard										
Snakes											
	Black Rat Snake										
	Common Garter Snake	42			16	9		3		70	4
	Eastern Earth Snake										
	Eastern Hognose Snake										
	Eastern Milk Snake	1			4					5	2
	Eastern Ribbon Snake										
	Eastern Worm Snake										
	Northern Black Racer	13			7	1		2		23	4
	Northern Brown Snake	9	1		9					19	3
	Northern Copperhead	17								17	1
	Northern Redbelly Snake										
	Northern Ringneck Snake	17	1		21	9				48	4
	Northern Water Snake	49						17		66	2
	Queen Snake	9						4		13	2
	Rough Green Snake										
	TOTAL # ENCOUNTERS	804	125	479	538	271	48	121	11	2397	
	TOTAL # SPECIES	27	4	5	8	8	7	11	3	29	

Table 9. Maximum chorus code[1] recorded for each species at each sampling site during Anura Calling Surveys at Valley Forge National Historical Park 2000-2001.

Species	Anura Calling Survey Site Number									
	21	22	23	24	24.5	25	26	27	28	29
Bullfrog	0	1	0	2	0	0	0	0	0	0
Eastern American Toad	1	1	2	1	2	1	2	0	0	0
Eastern Gray Treefrog	0	2	0	2	0	0	1	0	0	0
Northern Green Frog	0	1	0	1	0	1	0	0	0	0
Northern Spring Peeper	3	3	3	2	2	3	2	0	0	0
Pickerel Frog	0	1	0	0	0	2	0	0	0	0
Wood Frog	0	1	0	0	0	1	0	0	0	0

(1) Wisconsin Index Values, used for scoring the abundance of calling anurans during anura calling surveys (Mertz 1999):

Index Value 0	No amphibians calling.
Index Value 1	Individuals can be counted. There is space between calls.
Index Value 2	Calls of individuals can be distinguished but there is some overlapping of calls.
Index Value 3	Full chorus. Calls are constant, continuous, and overlapping.

Table 10. The number of times and person-hours effort for each survey method by sampling season at Valley Forge National Historical Park, 1999-2001.

Survey Method	Season							
	Fall 1999 (Sept. - November)		Spring 2000 (February - May)		Summer 2000 (June - August)		Fall 2000 (Sept. - November)	
	No. Times	Pers-Hrs	No. Times	Pers-Hrs	No. Times	Pers-Hrs	No. Times	Pers-Hrs
General Herpetological Collecting (Planned)	0	0	3	17.5	2	3.4	1	10.5
Natural Substrate Surveys in Forest	2	21.8	2	8.7	2	6.1	1	6.2
Natural Substrate Surveys in Runs	2	32.0	4	128.0	3	96.0	0	0
Coverboards	2	109.4	2	119.3	2	62.0	1	55.6
Drift Fences	2	168.7	2	208.5	2	121.8	1	85.8
Anura Calling Surveys	0	0	2	24.4	1	15.6	0	0
Basking Turtle Surveys	0	0	1	3.8	1	5.4	1	10.5
Aquatic Trapping	0	0	0	0	1	37.3	0	0
Total Person-Hours, All Methods Combined		331.9		510.2		347.6		168.6

Survey Method	Season							
	Spring 2001 (March - May)		Summer 2001 (June - August)		Fall 2001[1] (Sept. - November)		All Seasons 1999-2002	
	No. Times	Pers-Hrs	No. Times	Pers-Hrs	No. Times	Pers-Hrs	No. Times	Pers-Hrs
General Herpetological Collecting (Planned)	6	42.6	6	46.5	4	16.6	22	137.0
Natural Substrate Surveys in Forest	1	2.4	1	4.1	0	0	9	49.3
Natural Substrate Surveys in Runs	0	0	0	0	0	0	8.75	280.0
Coverboards	1	29.5	1	20.7	0	0	9	396.5
Drift Fences	1	81.2	1	68.7	0	0	9	734.5
Anura Calling Surveys	3	33.2	1	8.0	0	0	7	81.1
Basking Turtle Surveys	4	18.1	3	10.5	0	0	10	48.3
Aquatic Trapping	0	0	4	73.8	0	0	5	111.1
Total Person-Hours, All Methods Combined		207.0		232.3		16.6		**1837.8**

(1) This season includes one general herpetological collecting census conducted February 26, 2002.

This was followed closely by planned general herpetological collecting, with 5.7 person-hours per species. The least efficient methods were drift fence arrays and natural substrate surveys of runs, requiring 91.8 and 56.0 person-hours, respectively, for each species detected. The amount of time spent sampling during opportunistic general herpetological collecting was not recorded (hence not covered in Table 10), although dates and times of all animals encountered are in the database submitted with this report.

Habitat Use by Species

Herpetofauna species varied widely in the number of different habitat types in which each was found (Table 11). On average, a given species was found in 3.5 of the ten habitat types, with a range of from one to nine habitat types used per species. The northern water snake (*Nerodia sipedon sipedon*) was found in the most habitat types, missing only from roads. Other species found in considerably more habitat types than average included those found in eight habitat types (eastern American toad [*Bufo americanus americanus*] and pickerel frog [*Rana palustris*]), seven habitat types (common garter snake [*Thamnophis sirtalis sirtalis*]), and six habitat types (bullfrog [*Rana catesbeiana*] and red-backed salamander). All of these widespread species were also relatively abundant in the park, ranking in the top half in terms of frequency of sightings in this study. In contrast, more species were found in fewer than the average number of habitat types. Seven species were found in only two habitat types, and six species were found in only a single habitat type (queen snake, eastern milk snake [*Lampropeltis triangulum triangulum*], wood frog [*Rana sylvatica*], common musk turtle, common map turtle, and slimy salamander [*Plethodon glutinosus*]). Five of these were the least encountered species; all were in the bottom third in terms of frequency of encounter.

The 29 species also varied widely in their patterns of habitat use as quantified with the Habitat Diversity Index (HDI; Table 11). The trends based on HDI are similar to those based solely on number of habitat types, indicating that the habitat diversity index for a species is strongly correlated with the number of habitat types it uses. However, in some cases species using many habitat types scored lower HDIs than species using fewer habitat types. For example, the northern water snake, which used the most habitat types, ranked fifth in its habitat diversity. This occurred because this relatively abundant species was predominantly found in just a few aquatic habitat types, and only very rarely in terrestrial areas. Furthermore, some uncommon species had a relatively high HDI. For example, three species that ranked in the lowest one half based on abundance scored among the top six species in HDI. These were the eastern box turtle, longtail salamander [*Eurycea longicauda longicauda*], and northern black racer. Each was found in only four habitat types yet demonstrated no strong preference for any single type of habitat type. This high equitability of habitat use produced high HDI values.

Species Richness by Habitat Type

Because sampling effort was not uniform across all 10 habitat types, statistical analysis of the number of different species found in each habitat type could not be performed. Nevertheless, it is possible to gain some qualitative insight into the relative value of each habitat type for the herpetofauna (Table 11). The two most species-rich habitat types were lowland forest and wetlands, accounting for 16 and 15 species, respectively. Together, these two habitat types were

Table 11. Number of encounters by species and by habitat type, species richness by habitat type, and habitat use by species (number of habitats used and Habitat Diversity Index [HDI]) for the herpetofauna of Valley Forge National Historical Park, 1999-2001.

Group	Common Name	Habitat Type [1]										Habitat Use	
		UF	LF	TGM	WET	RUN	CRK	RIV	RD	RR	DEV	# Habitat Types	HDI
Salamanders													
	Eastern (Red-spotted) Newt				11				1			2	0.125
	Longtail Salamander		1			4	4				1	4	0.518
	Northern Dusky Salamander		1			150						2	0.017
	Northern Red Salamander	2				101						2	0.042
	Northern Two-lined Salamande	1	2			227	5					4	0.078
	Red-backed Salamander	641	531	79	6	11					1	6	0.415
	Slimy Salamander	1										1	0.000
Toads & Frogs													
	Bullfrog	1		1	16	1	9				1	6	0.502
	Eastern American Toad	10	32	4	13	3		1	5	1		8	0.680
	Eastern Gray Treefrog				7						1	2	0.164
	Fowler's Toad		1					15	1			3	0.193
	Northern Green Frog		2		11	4		1				4	0.452
	Northern Spring Peeper		1		21							2	0.080
	Pickerel Frog	4	3	1	17	10	5		3		1	8	0.742
	Wood Frog				3							1	0.000
Turtles													
	Common Map Turtle							2				1	0.000
	Common Musk Turtle							3				1	0.000
	Common Snapping Turtle				3		10	9				3	0.432
	Eastern Box Turtle		10	2	2				2			4	0.466
	Eastern Painted Turtle		1		22	1		20				4	0.381
	Red-eared Slider				20		2	36				3	0.338
Snakes													
	Common Garter Snake	19	18	26		1	2	3	1			7	0.621
	Eastern Milk Snake			5								1	0.000
	Northern Black Racer	1	4	14	4							4	0.455
	Northern Brown Snake		10	9								2	0.300
	Northern Copperhead	16							1			2	0.097
	Northern Ringneck Snake	31	13	2			1				1	5	0.404
	Northern Water Snake	1	1	4	4	3	49	1		1	2	9	0.461
	Queen Snake						13					1	0.000
	Total Number of Encounters	728	631	147	160	516	100	91	14	2	8		
	Total Number of Species	12	16	11	15	12	10	10	7	2	7		

(1) UF = upland forest, LF = lowland forest, TGM = tall grass meadow, WET = wetland, RUN = runs (small streams), CRK = Valley Creek, RIV = Schuylkill River, RD = roads (paved and unpaved) , RR = railroad, DEV = developed (inside buildings or on adjacent grounds).

used by 22 of the 29 (76%) species found at VAFO, which is more than any other two habitat types combined.

Five of the natural habitat types contained one or more species not detected in the others. For example, wetlands supported three species (eastern newt, eastern gray treefrog [*Hyla versicolor*], and wood frog) not found in any of the other six natural habitats. Two of the natural habitat types, lowland forest and runs, did not yield any species that were not also found in one or more of the other habitat types. However, the northern dusky salamander [*Desmognathus fuscus fuscus*] was found only in these two habitat types. Thus, the other five natural habitat types plus either the lowland forest or the runs yield the complete species list of 29 species.

Not surprisingly, the three anthropogenic habitat types (developed areas, roads, and railroad beds) contained the fewest species (seven, seven, and two, respectively). Nevertheless, 13 different species were found in these three habitat types, representing 45% of the species found during this inventory.

Discussion

Species Detected

This study was successful in making significant additions to the VAFO herpetofauna species list. Six of the 29 species detected represent new records for the park: eastern (red-spotted) newt encountered during planned general herpetological collecting, common musk turtle (basking turtle surveys, aquatic traps), common map turtle (planned general herpetological collecting), northern black racer (coverboards, drift fences, basking turtle surveys, general herpetological collecting), northern brown snake (coverboards, planned general herpetological collecting), and queen snake (basking turtle surveys, general herpetological collecting). In addition, earlier surveys (Carfioli 1998) detected another new species for the park (slimy salamander), which was also detected again during the current inventory.

This study detected 29 species out of a possible 56 species in the predicted list (Table 8), or only about 52% of the potential species. In hindsight, the most parsimonious combination of survey methods that would have detected all 29 species would have been general herpetological collecting, basking turtle surveys, anura calling surveys, and coverboards. An anura calling survey was required because the only wood frog detected by general herpetological collecting was captured after being detecting during an anura calling survey.

Salamanders (order Caudata)

Eastern Newt (also known as Red-spotted Newt, *Notophthalmus viridescens viridescens*)

This salamander represents a new VAFO record, having first been encountered at the northern park boundary on Washington Avenue during an anura calling survey. This discovery triggered intensive taxon-specific searching (a type of planned general herpetological collecting) in wetlands nearest this encounter, which eventually yielded 11 additional encounters in the desilting basin vernal ponds 5, 6, and 7 (site numbers 22.05, 22.06, 22.07). Three developmental stages were found, including aquatic larvae, a red eft subadult, and terrestrial adults, suggesting this species has a breeding population inside the park. Even if newts are inhabiting all of the desilting basins and associated area by Washington Avenue, this represents an area of only about 230,000 m^2 (23 ha).

Eastern newts are common throughout the Commonwealth, where they are found in a number of aquatic habitats, including temporary and permanent ponds, lakes, and slowly moving streams and creeks (Hulse et al. 2001). In addition, these newts appear to prefer areas in or near to woods (Hulse et al. 2001), making the VAFO desilting basins ideal habitat. Newts were not found in other VAFO aquatic habitats and were not detected by any of the seven standardized surveying methods.

Longtail Salamander (*Eurycea longicauda longicauda*)

This little-known resident at VAFO was found only 10 times during the inventory. This salamander was always associated with water, being found along Myers Run, Walnut Hill Run,

Valley Creek, next to a seep along the power cut north of the river, and beside the old cement pond at the Philander Knox Estate. Only two survey methods were able to detect this relatively rare amphibian, natural substrate survey along runs and general herpetological collecting.

Longtail salamanders occur throughout the entire Commonwealth, where they are found in a variety of terrestrial habitats, although during dry periods they tend to move closer to streams and ponds (Hulse et al. 2001). This species is primarily nocturnal, spending days under various cover objects, including bark, logs, rocks, and debris (Hulse et al. 2001). At VAFO, this species was always found under cover objects and was detected only by general herpetological collecting (10 encounters) and natural substrate surveys of runs (2 encounters).

Northern Dusky Salamander (*Desmognathus fuscus fuscus*)

Also a little-known resident of the park, this aquatic salamander was encountered 151 times. It was always associated with the smaller lotic bodies of water, including Stirling's, Fisher's, Welch, Myer's, Fawn, and Lamb Runs, plus the spring emanating from the former Fisher's Bottling Plant on Mount Misery. Duskys were not encountered along Valley Creek or along the Schuylkill River. These observations are consistent with the known ecology of this species, which is wide-spread throughout the state of Pennsylvania, preferring small woodland streams with abundant cover objects (Hulse et al. 2001). Similar to the longtail salamander, duskys where found only by general herpetological collecting (about 3% of encounters) and natural substrate surveys of runs (97%).

Northern Red Salamander (*Pseudotriton ruber ruber*)

This beautiful salamander, a little-known resident of the park, was found 103 times, almost always in or immediately adjacent to water. Locations include Fisher's and Stirling's Runs, the spring inside the former Fisher's Bottling plant, and atop Mount Misery (one individual caught in a drift fence bucket trap, about 125 m from the Bottling Plant). These observations support the general findings that this state-wide inhabitant prefers cool, clear streams that are shallow and offer abundant rocks on the bottom (Hulse et al. 2001). Larvae hatch and develop in these aquatic habitats, but adults may occasionally be found in hilly, forested areas up to 300 m from water (Hulse et al. 2001). This salamander was detected most frequently in VAFO during natural substrate surveys of runs (95% of encounters), rarely during general herpetological collecting (4%), and once at a drift fence.

Northern Two-lined Salamander (*Eurycea bislineata*)

Already documented as a well-known VAFO resident, this salamander was the second most frequently encountered species in the park, with 235 encounters. This streamside salamander was much more widespread than the other three steamside species described above, being found at Fisher's, Stirling's, Myer's, Lamb, and Welch Runs, at the former Fisher's Bottling Plant, and along Valley Creek. With a state-wide range, this common species is known for preferring small and medium-sized streams with gravel or sand substrates (Hulse et al. 2001). As with other streamside salamanders, larvae are born and develop in streams while adults tend to frequent the

edges of water. This species was detected primarily by natural substrate surveys of runs (95% of encounters) and occasionally by general herpetological collecting (5%).

Red-backed Salamander (*Plethodon cinereus*)

A ubiquitous, well-known resident, this ecologically important salamander (Burton and Likens 1975) was encountered 1269 times throughout the park, primarily in upland and lowland forest habitat types. Petranka (1998) describes their habitat as limited to leaf litter in forested areas, so it was surprising to find a number of these terrestrial salamanders in tall grass meadows at VAFO. Four were found under coverboards in the meadow behind Lord Stirling's Quarters (site 12, at least 40 m from the nearest forest), 44 caught by the drift fence at meadow site 17 (at least 50 m from the nearest forest), and 24 more found around this drift fence when opening traps or conducting repairs. Hulse et al. (2001) does report that in Pennsylvania this species is known to inhabit disturbed areas at the borders of forests, such as railroad rights-of-way, but no other documentation of red-backed salamanders in grasslands this far from forest has been found. Three other tall grass meadow sampling sites (13, 16, and 20) that were close to forest (within 40–50 m) yielded no red-backed salamanders. The other five meadow sites (12, 14, 15, 18, and 19), which were much further from forest (120-430 m), also did not produce any encounters for this species. Red-backed salamanders were detected by five of the eight survey methods, including coverboards (38% of encounters), general herpetological collecting (34%), drift fences (19%), natural substrate surveys in forest (9%) and in runs (< 1%).

Slimy Salamander (*Plethodon glutinosus*)

Previously reported at VAFO from just a single sighting (Carfioli 1998), this secretive (Hulse et al. 2001), little-known terrestrial salamander was found only once during the current inventory. These two sightings represent a new record for the park. The most recent encounter occurred under an oak coverboard in a rocky forested area atop Mount Misery. Because this species is solitary and often nocturnal, its numbers are often underestimated (Hulse et al. 2001). In addition, this species may have one of the shortest activities seasons of all salamanders (Pfingsten and Downs 1989), making it even more difficult to detect. This species typically is found in densely forested areas, especially where there is abundant rocks and logs (Hulse et al. 2001). Hence, it is likely that this species occurs at additional locations in VAFO, particularly in the moist, rocky ravines in the forested areas of Mount Misery and Mount Joy.

Toads and Frogs (order Anura)

Note: The anura calling surveys sampled an area with a radius of approximately 500 m (see "Sampling Design" above). Thus, habitat descriptions based on these data reflect conditions nearest the observers and might not accurately represent the exact habitat occupied by calling anurans.

Bullfrog (*Rana catesbeiana*)

Previously a little-known resident at VAFO, this large ranid of state-wide distribution (Hulse et al. 2001) was encountered 33 times in a wide variety of habitat types. Bullfrogs were found in

and along Valley Creek, Fisher's and Welch Runs, the desilting basins and associated wetlands, Fatlands Pond, and the reflection pool at the Philander Knox Estate. Hulse et al. (2001) describe its required habitat in Pennsylvania as being permanent bodies of water, including ponds, lakes, streams, and rivers. In VAFO, the desilting basins are temporary and Fatlands Pond dried up during the summer drought of 1999, so apparently the bullfrog can also inhabit seasonal wetlands as well as permanent bodies of water. Bullfrogs were most frequently detected during general herpetological collecting (45% of encounters), occasionally during basking turtle surveys (28%) and anura calling surveys (24%), and only once during aquatic trapping (3%).

Eastern American Toad (*Bufo americanus*)

A well-known park resident, this species was the most commonly encountered anuran. It was recorded 69 times throughout virtually the entire park, being found in eight of the 10 habitat categories and absent only from Valley Creek and developed areas (Table 11). These common amphibians were also found over the full range of elevations in the park, from the shores of the Schuylkill River to the top of Mount Misery. These observations are consistent with the known distribution of this state-wide habitat generalist, which is found in a wide range of terrestrial habitats from open meadows to dense forests (Hulse et al. 2001). Eastern American toads were most frequently detected during general herpetological collecting (62% of encounters), less often by drift fences (17%) and anura calling surveys (12%), and only rarely by coverboards (4%) and natural substrate surveys in forest (4%).

Eastern Gray Treefrog (*Hyla versicolor*)

Though a well-known resident, this uncommon Hylid was found only once south of the Schuylkill River, where it was heard calling south of the wetland at site 26 near Huntington's Quarters. Seven additional encounters occurred north of the river, with six sightings in the desilting basins and one from the area of the abandoned garage by Fatlands Pond. All of these encounters occurred near water, consistent with the general observation that this state-wide species is generally found near pools, ponds, or roadside ditches (Hulse et al. 2001). Treefrogs were most frequently detected by anura calling surveys (50% of encounters), and less frequently by basking turtle surveys (25%) and general herpetological collecting (25%).

Fowler's Toad (*Bufo fowleri*)

This little-known toad was relatively uncommon and appeared limited in distribution to habitats north of the river. One adult was encountered on a rainy night along the entrance road by Walnut Hill that runs by the old stone barn. Sixteen other adults were seen along the banks of the river, between Walnut Hill and Boy Scout Field, including one group of 15 adult males calling from a sandy bank. Thus, although the species appears to be breeding in the park, it might be limited to a geographic area of roughly 7500 m^2 (or 0.75 ha). These observations are consistent with the known distribution of this species in Pennsylvania. Limited to the southern two-thirds of the state, Fowler's toad is a habitat specialist, preferring open habitats with well-drained sandy or gravelly soils (Hulse et al. 2001). Thus, these toads tend to be found near streams and rivers and away from upland or wooded habitats. Because VAFO has so few sandy areas (see "Eastern

Spadefoot Toad" below), the park appears to contain very little suitable habitat. This species was detected only by general herpetological collecting.

Northern Green Frog (*Rana clamitans melanota*)

This little-known resident species was encountered only 18 times, making it much less common than two of its congeners, the Bullfrog and the Pickerel Frog. The northern green frog was found in a variety of wet habitats, including the desilting basins, Fatlands Pond, the flooded woodland at site 25 between the railroad tracks and the river, Welch Run, Fisher's Run by the former bottling plant, and the north bank of the river. A single individual was caught in a pitfall bucket at the drift fence at site 11, approximately 60 m from the nearest permanent water at Welch Run. These localities are consistent with the known habitat requirements of this state-wide species. Northern green frogs are habitat generalists, using virtually any type of aquatic habitat except for areas with very fast current (Hulse et al. 2001). This species was detected most often by general herpetological collecting (50% of encounters) and calling anura surveys (44%) and detected once by drift fence (5%).

Northern Spring Peeper (*Pseudacris crucifer crucifer*)

Previously little-known at VAFO, this tiny frog was heard at more anura calling survey sites (seven out of 10) than any other anuran, accounting for 16 out of 48 (33%) total anura calling survey records for all species combined. These seven sites included the slough north of the river near the Meadow Grove springhouse (site 21), the desilting basins (site 22), a grassy wetland in the floodplain of the river (site 23), Fatlands Pond (site 24), the pair of vernal pools at the base of Walnut Hill (site 24.5), the wooded seasonal wetland between the river and the railroad tracks (site 25), and the small spring and associated grassy wetland behind Huntington's Quarters (site 26). Somewhat surprisingly, peepers were not detected anywhere in the park other than these seven anura calling survey sites. These encounters are consistent with the known ecology of this state-wide species, which typically spends the nonbreeding season in deciduous forests, swamps and adjacent marshy fields and meadows but moves more into nonwooded wet areas to reproduce (Hulse et al. 2001). This species was detected only during anura calling surveys (73% of encounters) and during general herpetological collecting (27%) done with calling surveys.

Pickerel Frog (*Rana palustris*)

Unlike the peeper, pickerel frogs were detected more often by methods other than anura calling surveys and at many sites other than the 10 anura calling survey listening sites. Of the 44 total encounters of this well-known resident, only three (7%) were during anura calling surveys. The other encounters occurred during general herpetological collecting (86%), basking turtle surveys (5%), and at a drift fence (2%). Habitat types used in the park were primarily aquatic: wetlands (39%), runs (23%), and Valley Creek (11%). In addition, encounters occurred along grassy unpaved roadsides (7%), and one individual was captured in a drift fence bucket trap in lowland forest (site 11), approximately 60 m from Welch Run. This state-wide species is considered semi-aquatic, frequenting a wide variety of aquatic habitats during spring breeding, but moving into more terrestrial habitats later in their activity season (Hulse et al. 2001). These terrestrial habitats tend to be mesic and include woods, open fields, and meadows. Thus, the occurrence of

this species in lowland forest and along roadsides at VAFO is consistent with nonbreeding habitat preferences.

Wood Frog (*Rana sylvatica*)

This mid-sized but secretive (Shaffer 1991) frog proved quite elusive. A little-known resident, it was detected only twice, being heard calling at the lowest chorus frequency at two anura calling survey sites (22 and 25) on the same night. An additional general herpetological collecting record represents the capture and processing of one of the above individuals. Thus, probably fewer than five individuals were encountered in the park. This species is a explosive breeder, meaning that most individuals in a given population come to the breeding pools nearly in synchrony and then disappear; thus it is easy to miss this species unless the timing of the anura calling survey happens to coincide exactly with the breeding pulse. However, its preferred forested habitat (Hulse et al. 2001; Shaffer 1991) in the vicinity of the breeding pools was searched many times during the inventory and not a single wood frog was found by this method. It must be concluded that, despite an apparent abundance of suitable habitat and breeding pools, this state-wide species (Hulse et al. 2001) is extremely rare at VAFO.

Turtles (order Testudines)

Common Map Turtle (*Graptemys geographica*)

This denizen of large rivers and lakes (Hulse et al. 2001) was spotted only twice in the park, both times being seen basking along the north bank of the Schuylkill River during general herpetological collecting. The two encounters occurred about eight months apart at locations separated by about 3.1 km (as the river flows). This species represents a new record for VAFO. Although previously reported from sections of Montgomery County along the Delaware River (Hulse et al. 2001), this occurrence so far upstream along the Schuylkill River may represent a recent range extension for this species.

Common Musk Turtle (*Sternotherus odoratus*)

This small aquatic turtle represents a new record for VAFO, which is inside the geographic range for this species (Hulse et al. 2001). It was encountered once during aquatic trapping along the north bank of the Schuylkill River, where Myer's Run enters, and also during a basking turtle survey on the south bank of the river, approximately 1240 m downstream from the trapping location. Fond of slower waters with soft mud bottoms (Behler and King 1996), the river provides ideal habitat, although this inconspicuous little reptile (Shaffer 1991) might also occasionally occur in the lower reaches of several of the runs in VAFO and possibly in the slower sections of Valley Creek.

Common Snapping Turtle (*Chelydra serpentina serpentina*)

A little-known VAFO resident, this largest of the native turtles of the Commonwealth (Hulse et al. 2001) was encountered 22 times. It was most often detected during aquatic trapping (41% of encounters) and general herpetological collecting (36%), and less often seen during basking

turtle surveys (23%). Somewhat of a habitat generalist (Hulse et al. 2001), this carnivore was seen occasionally in the desilting basins and frequently along Valley Creek, yet when these localities were trapped, no turtles of any species were caught. Along the Schuylkill River, however, snappers were captured at five out of the 10 trapping sites. Of the nine trap-encounters along the river, seven were attracted to the carnivore bait, while two came to traps baited for herbivores. Found throughout the Commonwealth, this species is a habitat generalist that can be found in almost every freshwater habitat, and it is known for making cross-country treks between aquatic habitats (Hulse et al. 2001). Thus, this species might also occur at Fatlands Pond and perhaps even in some of the larger pools found in any of the runs.

Eastern Box Turtle (*Terrapene carolina carolina*)

Though a well-known park resident, and once considered a common backyard inhabitant, box turtle populations throughout the Northeast have been decreasing dramatically in recent years (Lieberman 1994), causing concern among herpetologists regarding the long-term future of this intelligent (Tyning 1990) chelonian. Two threats to this species are of special concern at VAFO. Box turtles often suffer heavy road mortality (Hulse et al. 2001; Pauley 1992; one was found dead on a VAFO road) and, because they are very popular as pets (Conant and Collins 1998; Lieberman 1994), are subject to heavy collecting by visitors. Accordingly, this was a species of concern for the VAFO resource managers, and all individuals were given an unique identification mark. This terrestrial turtle was not particularly common at VAFO, being encountered only 16 times. Because of the identification marks, these were all known to be different individuals; in fact, the same individual was never recaptured. All encounters were during general herpetological collecting; no box turtles were detected by any of the standardized survey methods. Habitat preferences at VAFO were strong, with 62% of encounters occurring in lowland forest. Other habitat types included tall grass meadows, wetlands, and roads (12% each). These observations are consistent with other reports from Pennsylvania, where this species is found throughout most of the lower two-thirds of the state (Hulse et al. 2001). Eastern box turtles are the only terrestrial turtles in the Northeast, most frequently found in deciduous forest and ecotones between forest and fields. During dry spells, they may move into more mesic habitats, including marshy areas (Hulse et al. 2001).

Eastern Painted Turtle (*Chrysemys picta picta*)

A well-known and common resident of the park, this species was the most frequently encountered native turtle. With a total of 44 encounters, it was detected only during basking turtle surveys (68% of encounters) and general herpetological collecting (32%). This reptile was found in greatest numbers basking along both banks of the Schuylkill River. It was found in lesser numbers in the desilting basins, and rarely in seasonal sloughs of the river (one on the south side and one on the north side at site 21). One individual was found dead on the railroad tracks near anura calling survey site 25. Surprisingly, this species was never found along Valley Creek, despite an abundance of snapping turtles and red-eared sliders (*Trachemys scripta elegans*) found there. The absence of eastern painted turtles from Valley Creek is consistent with their preference for slower bodies of water and tendency to avoid small, swift streams (Behler and King 1996, Hulse et al. 2001). Otherwise, this species is found in most other freshwater

habitats in the Northeast (Hulse et al. 2001), and thus might also be found at Fatlands Pond and the wooded seasonal wetland near site 25.

Red-eared Slider (*Trachemys scripta elegans*)

Previously a little-known resident, the red-eared slider turtle turned out to be the most commonly encountered turtle during this survey, with 58 sightings. It was detected only during basking turtle surveys (79% of encounters) and general herpetological collecting (21%). Habitat preferences included both banks of the Schuylkill River (62% of encounters), wetlands (primarily the desilting basins, 34%), and two encounters from Valley Creek (3%). These observations of habitat use are somewhat consistent with reports from West Virginia (Green and Pauley 1987) that indicate a preference for quite water with a mud bottom and abundant vegetation. The Schuylkill River is generally slow with a mud bottom, but lacks abundant vegetation. The desilting basins appear more similar to the reported preferred habitat.

The slider is an exotic species with an established colony documented in Maryland that is disjunct from its natural geographic range (Conant and Collins 1998). The source of colonists is most likely pets that escaped or were released into the wild. However, this species is not mentioned as being an established resident in Pennsylvania by McCoy (1982), Shaffer (1991), or Hulse et al. (2001). In the current inventory, observers were close enough to estimate carapace length five times, with estimates ranging from 10 to 20 cm. This represents a considerable range in probable age class, suggesting that this species is reproducing in or near VAFO.

Snakes (order Squamata, suborder Serpentes)

Common Garter Snake (*Thamnophis sirtalis sirtalis*)

This common, mid-sized colubrid was a well-known VAFO resident and the most frequently encountered snake in this inventory. The 70 sightings for this species occurred at virtually all elevations and most of the habitat types of the park, giving this species the highest HDI of any snake at VAFO. It was found under coverboards in upland forest (sites 2 and 3), lowland forest (site 7), and tall grass meadows (sites 12, 13, 15, and 16). It was found at drift fences in upland forest (site 5) and tall grass meadow (site 20). In addition to these habitat types, it was also encountered during basking turtle surveys or general herpetological collecting along Valley Creek, on both banks of the river, along the power line right-of-way, on scree slopes and rock piles atop Mount Misery, along Fisher's and Lamb Runs, in the quarry north of the Visitor Center, around the Nature Center, and an individual was found roadkilled on Inner Line Drive. It was not recorded from the vicinity of the desilting basins, but almost certainly occurs there as well. Most of the encounters were during general herpetological collecting (60% of encounters), followed by coverboards (23%), drift fences (13%), and basking turtle surveys (4%). The preferred habitats at VAFO were tall grass meadows (37% of encounters), upland forest (27%), and lowland forest (26%). This species was only rarely detected along the runs, Valley Creek, and the Schuylkill River. These overall observations on habitat use are consistent with the literature on this species, as summarized by Hulse et al. (2001). They describe this state-wide species as the most common snake in the Northeast, with the largest range of habitats used by any snake.

Eastern Milk Snake (*Lampropeltis triangulum triangulum*)

Previously documented as a little-known resident at VAFO, this uncommon and secretive (Shaffer 1991) snake was encountered only five times in the park. All encounters were under coverboards in tall grass meadow at site 12 (at stations 5, 7, and 8). Behavioral observations and the variation in body sizes suggest that VAFO may contain a small, reproducing population of this species. During one coverboard survey, three adults were seen together at a single board, apparently engaged in courtship behavior. In addition, snout-vent-lengths (SVL) in this inventory ranged from 29 to 80 cm. Because average SVLs for Pennsylvania specimens are 72.6 cm for adult males, 67.7 cm for adult females, and 18.7 cm for hatchlings (Hulse et al. 2001), it is likely that the VAFO population contains a mix of adult and subadult individuals. With its apparent preference for grassy habitats at VAFO, this species may be at special risk from mowing. This species occurs throughout the state, typically being found in open habitats, ecotones, around human structures, and in deciduous forest (Hulse et al. 2001). Thus, there appears to be abundant suitable habitat in the park. It is therefore possible that this species occurs at other locations in VAFO but was missed by the current inventory. The coverboards at site 12 were closer to the forest than the coverboards at the four other meadow sites. Perhaps these other coverboard transects were too far beyond the forest/meadow ecotone to attract any eastern milk snakes.

Northern Black Racer (*Coluber constrictor constrictor*)

This locally abundant large colubrid represents a new record for the park. With 23 sightings, this species was encountered in tall grass meadows under coverboards (sites 12 and 16) and in a funnel trap at a drift fence (site 17). During basking turtle surveys and general herpetological collecting it was also found by the slough north of the river near the Meadow Grove springhouse (site 21), around the desilting basins, along the Bikeway, as well as in both lowland and upland forest. This species demonstrated a strong habitat preference for the tall grass meadows (61% of observations), with only scattered occurrences in wetlands and lowland forest (17% each). These observations are consistent with known patterns of habitat use for this state-wide species, which prefers open country, including meadows, old fields, utility rights-of-way, and farmland (Hulse et al. 2001). Being a diurnal inhabitant of open habitats (Hulse et al. 2001), it is not surprising that it was most often encountered during general herpetological collecting (57% of encounters), followed by detection under coverboards in tall grass meadows (30%).

Northern Brown Snake (*Storeria dekayi dekayi*)

This locally abundant snake represents a new record for the park. Although encountered 19 times, this small, inconspicuous reptile (Shaffer 1991) was found only at site 9 and vicinity (53% of encounters, in lowland forest) and the nearby site 13 (47% of encounters, in tall grass meadow), giving a documented geographic range at VAFO of possibly only about 75,000 m^2 (7.5 ha). The area near site 9 contains abundant debris from a former homestead, with most individuals being found under pieces of refuse. At site 13, all individuals were found underneath coverboards. These observations are typical of this species in Pennsylvania and the Northeast, where it has been recorded in many different habitats, including forest and grasslands, as long as there are sufficient cover objects (Hulse et al. 2001). The most dense population in the

Commonwealth was reported from a "shanty town" near Lancaster, with 603 individuals collected in an area of about 2.1 ha (Ernst and Barbour 1989).

Northern Copperhead (*Agkistrodon contortrix mokasen*)

Previously documented as a little-known resident at VAFO, this venomous reptile was encountered 16 times (94% of encounters) during general herpetological collecting on Mount Misery, primarily on rocky slopes in upland forest, and one road-killed individual (6%) was reported on Route 252 along Valley Creek between Mount Misery and Mount Joy (M. Carfioli, pers. comm.). Unsubstantiated reports by visitors and two reported bites in 1993 (M. Carfioli, pers. comm.) also suggest this species likely occurs on Mount Joy, although none was found despite considerable searching. The largest rock pile atop Mount Misery is a known birthing area for this species (H. Tiebout and M. Carfioli, unpublished obs.), which thus has a reproducing population in the park. Hulse et al. (2001) describe this species as preferring deciduous woodlands and associated clearings, as well as rocky ledges and rocky open habitats. These habitats are similar to those found to be preferred in this inventory, although these habitats are often used for basking and thus the snakes may be more apparent when using them. However, northern copperheads can also be found near streams and swamps, and around farms and abandoned lumber operations (Shaffer 1991). Thus, this species may be more widespread throughout VAFO than indicated by this inventory, which may have failed to detect individuals elsewhere due to their cryptic coloration and secretive nature (Hulse et al. 2001) when not basking.

Northern Ringneck Snake (*Diadophis punctatus edwardsii*)

This small, secretive (Hulse et al. 2001), yet well-known VAFO resident was encountered 48 times. It was nearly always found in forested habitat types (65% of encounters were in upland forest, 27% in lowland forest) under natural or artificial cover objects. The upland forest sites included coverboard sites 1, 2, and 3, natural substrate survey of forest site 1, and drift fence site 4. Lowland forest sites included coverboard site 6, and drift fence sites 10 and 11. This species was also found at tall grass meadow coverboard site 12, the lowland forest around the amphitheater, along Valley Creek, on the scree slopes of Mount Misery, and in the lowland forest between the abandoned railroad grade and Route 422. These documented habitat types are similar to those found in other studies. As summarized in Hulse et al. (2001), the preferred habitats for this species are generally in or near to deciduous woods, including fields, rocky hillsides, and the shores of streams and rivers (Hulse et al. 2001). The primary determinant of habitat quality for this state-wide species is the abundance of suitable cover objects, particularly rocks. Overall, this species was most readily detected by coverboards (44% of encounters) and general herpetological collecting (35%).

Northern Water Snake (*Nerodia sipedon sipedon*)

This aquatic snake, although a little-known resident at VAFO, was encountered 66 times in this inventory. All observations were made during general herpetological collecting (74% of encounters) or basking turtle surveys (26%) and usually occurred in, over, or near water. Valley Creek hosted the most sightings (74% of encounters), with snakes commonly found at the

gabion, the vicinity of the covered bridge, the vicinity of the Wilson Road Bridge by Lafayette's Quarters, and at any of the piles of debris accumulated by fallen branches and tree trunks. Water snakes were also found along both banks of the Schuylkill River and in and around the desilting basins and the vernal ponds at the base of Walnut Hill. One newborn water snake was found dead on the railroad tracks approximately 100 m west from site 25. These sightings are consistent with the known habitat preferences of this species in Pennsylvania, where this state-wide species inhabits most aquatic and semi-aquatic habitats (Hulse et al. 2001). The northern water snake was the second most frequently encountered snake of this inventory, consistent with the assertion by Hulse et al. (2001) that this is one of the most common snakes in the Northeast.

Queen Snake (*Regina septemvittata*)

The taxon-specific search (see "Sampling Design" above) for the queen snake focused on areas of the park that appeared to be the best habitat for this species (Shaffer 1991; Hulse et al. 2001). These target areas included sections of Valley Creek and various runs where there was abundant loose rock along the banks and/or low vegetation overhanging the water. This small to mid-sized, highly aquatic snake (Shaffer 1991) was detected 13 times during the survey, 69% of encounters were during general herpetological collecting, with the remaining 31% during basking turtle surveys. This snake was very restricted in habitat use, being found only on the banks of Valley Creek. Most observations were in three general areas: the site of an old gabion that has fallen down (approximately 200 m downstream from the site of the former foot bridge), the gabion (approximately 200 m upstream from the site of the former foot bridge), and the vicinity of the Wilson Road Bridge by Lafayette's Quarters. These general areas match the typical habitat described for this species, which is small, clear, rapid water with an abundance of rock on the bottom and shores, overhanging vegetation, and the presence of crayfish for prey. However, other areas searched, especially along Welch Run, also matched this description but yielded no queen snakes. This species represents a new record for the park.

Habitat Use by Species

It was found that most herpetofaunal species were habitat generalists, using a wide range of different habitat types. Only six relatively rare species appeared to be habitat specialists, being found in just a single habitat category. In addition, some species with relatively narrow habitat preferences, found in just one or two habitat types, were not found in many areas of the park where apparently appropriate habitat occurred. For example, the northern brown snake was encountered fairly frequently in one tall grass meadow and in one lowland forest patch, but not found in these same habitat types elsewhere in the park. These two trends, single species which use multiple habitat types and the absence of some species from apparently suitable habitat, make it very difficult to predict the presence of a given species for an area based solely on the availability of habitat.

Species Richness by Habitat Type

The two most species-rich habitat types, wetlands and lowland forest, typically occur together (most of the wetlands are interspersed amongst lowland forest), with the largest block found

north of the Schuylkill River. Because of its value in supporting the most species, this habitat complex should be considered the "herpetofauna hot spot" of VAFO.

Of the seven natural habitat types, two (lowland forest and runs) were found not to harbor any species not found in one or more of the other natural habitats. Nevertheless, both of these habitat types are likely extremely important to the herpetofauna of VAFO for two reasons. First, in terms of contributing to overall species richness of the park, only these two habitats contained the northern dusky salamander. Second, these habitat types were important demographically, supporting large numbers of individuals of some species and providing critical breeding habitat. In particular, lowland forest contained the second highest abundance of individuals detected, accounting for 26% of the animals found in the park, and the highest number of species, accounting for 59% of the herpefauna richness. The runs accounted for over 21% of the individual animals and was the only habitat type containing appreciable numbers of three of the streamside salamanders (northern red, northern dusky, and northern two-lined). These species depend on small, rocky springs and streams, as exemplified by this habitat type, for reproduction (Hulse et al. 2001). Thus, to maintain all 29 herpetofauna species at VAFO, all of the natural habitat types are considered essential.

In addition to the importance of the seven natural habitat types, many species (approximately 45%) exhibited limited use of the three anthropogenic habitat types (roads, railroads, and developed areas). In order to minimize disruption to park visitors and to insure observer safety, these habitat types were not included in the standardized sampling surveys. Consequently, the actual use of these habitat types by herpetofauna is likely underestimated, although none of them contained species not found elsewhere in the park.

Species on the Predicted List Not Detected

Salamanders (order Caudata)

Four-toed Salamander (*Hemidactylium scutatum*) - Possible Extirpated Resident

Because this species was not found by other investigators, not reported on VAFO Wildlife Observation Cards (WOCs), and has no recent reliable records from Chester, Montgomery, or Berks Counties (Hulse et al. 2001), this secretive habitat-specialist (Shaffer 1991) is likely not currently present at VAFO. However, VAFO is well within the geographic distribution for this species (Hulse et al. 2001), and the park does contain some suitable habitat in the form of woodland pools with sphagnum moss (Shaffer 1991). Furthermore, Hulse et al. (2001) report that several historical populations in eastern Pennsylvania may have been locally extirpated due to habitat modification and destruction. Thus, it is possible that this species may have inhabited VAFO sometime in the past.

Jefferson Salamander (*Ambystoma jeffersonianum*) - Probable Nonresident

This secretive species (Hulse et al. 2001) was not found by other investigators, not reported on VAFO WOCs, and has no recent reliable records from Chester, Montgomery, or Berks Counties (Hulse et al. 2001). Therefore, this salamander is likely not present at VAFO. Although the park

contains suitable forested habitat for this species, VAFO is completely outside of the current geographic range for this species (Hulse et al. 2001). However, these authors do mention that there exist unsubstantiated records from the southeast Pennsylvania coastal plain. Accordingly, because VAFO is located between the coastal plain and the documented species range, it is possible that this animal once occupied the park. As with the two other species of *Ambystoma* that have not been documented in the park (see below), lack of suitable vernal pool breeding habitats may be one reason for their absence. Acid precipitation may also play a limiting role (Hulse et al. 2001).

Marbled Salamander (*Ambystoma opacum*) - Possible Extirpated Resident

Although not found by other investigators and not reported on VAFO WOCs, there are recent reliable records from Montgomery and Berks Counties (Hulse et al. 2001). VAFO is thus well within the species current geographic range, and the park contains ample suitable forested habitat. This species may face the same limitations described above for the Jefferson salamander.

Mudpuppy (*Necturus maculosus maculosus*) - Probable Nonresident

This highly aquatic salamander (Shaffer 1991) was not found by other investigators, not reported on VAFO WOCs, and has no recent reliable records from Chester, Montgomery, or Berks Counties (Hulse et al. 2001). Therefore, this amphibian is likely not present at VAFO. This species was included in the predicted list (Table 1) because of a single record from the Delaware River near the park. However, VAFO is more than 200 km outside of the current geographic distribution (Hulse et al. 2001), and the authenticity of the Delaware River record has been called into question (Hulse et al. 2001). Accordingly, it is unlikely that this species has ever been present at VAFO.

Northern Spring Salamander (*Gyrinophilus porphyriticus porphyriticus*) - Indeterminate

This species was not found by other investigators, not reported on VAFO WOCs, and has no recent reliable records from Chester or Montgomery Counties (Hulse et al. 2001). Accordingly, this habitat-specialist (Hulse et al. 2001) remains indeterminate in status. Two recent records exist for nearby Berks County, and the current geographic range just barely includes VAFO (Hulse et al. 2001). The park does contain some suitably cool, clean springs that could support this species (Shaffer 1991), but exhaustive searches of these habitats failed to detect any individuals.

Spotted Salamander (*Ambystoma maculatum*) - Possible Extirpated Resident

Although this species was not found by other investigators and not reported on VAFO WOCs, this secretive salamander (Hulse et al. 2001) has a number of recent reliable records from Chester, Montgomery, and Berks Counties (Hulse et al. 2001). Thus, the park is well within the geographic range for this species. As found for the other *Ambystoma* salamanders, the park appears to contain ample suitable forested habitat, but this species may face the same limitations described above for the Jefferson salamander.

Toads and Frogs (order Anura)

Eastern Spadefoot Toad (*Scaphiopus holbrooki holbrooki*) - Possible Current Resident

This species is known to be difficult to document because it is completely nocturnal, secretive, fossorial, and exhibits unpredictable surface activity (Tyning 1990; Hulse et al. 2001). This toad spends long periods of time underground, emerging to feed and move about only following periods of heavy rain. Breeding typically follows only the heaviest rainfalls of 5.1 cm (2.0 in) or more (Tyning 1990). It is an explosive breeder, with reproduction for a local population lasting only one or two nights. Furthermore, a given population might reproduce less frequently than once per decade (Hulse et al. 2001).

In Pennsylvania, breeding has been documented in April, July, and August. To determine when this toad might have had an opportunity to breed at VAFO, rainfall records from the National Weather Service station in Philadelphia (available online from the Pennsylvania State Climatologist website at http://pasc.met.psu.edu/cgi-bin/daily.cgi) were analyzed for the months March through September. This range of dates starts one month prior to and ends one month later than the known months for spadefoot toad reproduction in Pennsylvania, thereby providing for the considerable variation in breeding dates typical of this species. During the current inventory period, rainfall events that could potentially induce spadefoot breeding (defined as $\geq$ 5.1 cm [2.0 in] falling within 48 h) occurred five times. The heaviest rainfall (17.73 cm) fell in mid-September 1999, when Hurricane Floyd made landfall. At this time, transects were being established and the actual field sampling had not yet begun. Although this date is somewhat outside the known breeding period in Pennsylvania, spadefoots do breed as late as September and October farther to the south (e.g., West Virginia, Green and Pauley 1987). Thus, it is possible the toads bred at this time and were missed by the inventory. Four other significant rainfall events occurred during the field sampling: March 21/22 2000 (8.13 cm), September 3/4 2000 (6.96 cm), September 25/26 2000 (5.16 cm), and June 16/17 2001 (8.48 cm). None of these events were followed in the next 2-3 d by an anura calling survey, so again breeding activity of this species might have been missed by the inventory.

Spadefoot toads have been found at VAFO by other investigators (Cypher et al. 1985b) and reported on VAFO WOCs, but there are no current reliable records from Chester, Montgomery, or Berks Counties, or anywhere else in southeastern Pennsylvania (Hulse et al. 2001). Furthermore, VAFO falls outside of the nearest part of this species geographic range, which includes all of New Jersey (Hulse et al. 2001). However, Hulse et al. (2001) indicate there are unsubstantiated reports of this species in the Delaware Valley of Pennsylvania, from the Philadelphia area north to Monroe County. These authors suggest that if such populations did exist historically, they have been extirpated due to urban development and industrialization. Because this species has been reported from the park and other populations have historically been reported nearby, there remains some small chance this species is persisting at a very low density at VAFO. Based on its preferred habitat of sandy soils along floodplains and in agricultural fields (Hulse et al. 2001), the most likely area to support this species at VAFO is the chain of desilting basins north of the Schuylkill River. This area has numerous vernal pools, is close to some sandy banks along the river, and the local soil has a very sandy texture from the abundance of coal silt.

New Jersey Chorus Frog (*Pseudacris triseriata kalmi*) - Probable Nonresident

This species was placed on the predicted list (Table 1) because of an historical record from Montgomery County (Wild Resource Conservation Fund 1995). However, this rare frog has not been found by other investigators, not been reported on VAFO WOCs, and there are no recent reliable records from Chester, Montgomery, or Berks Counties (Hulse et al. 2001). The nearest substantiated records for this state-listed subspecies are from the extreme eastern tip of Bucks County, putting VAFO well outside the current geographic distribution. It is unlikely that this species was ever present in the park.

Northern Cricket Frog (*Acris crepitans crepitans*) - Indeterminate

Although not found by other investigators and not reported on VAFO WOCs, this species has recent reliable records from Montgomery County. Because VAFO falls well within its current geographic range (Hulse et al. 2001) and appears to have some suitable habitat in the form of permanent water and open habitat with abundant vegetation (Shaffer 1991), this diminutive hylid remains indeterminate in status.

Northern Leopard Frog (*Rana pipiens*) - Possible Current Resident

Despite conducting seven Anura Calling Surveys and repeated searches in appropriate wetlands, fields, meadows, and woodlands (Hulse et al. 2001), this species was not detected. However, it was documented at VAFO prior to 1996 (Yahner et al. 1999) and has recent reliable records from Chester and Berks Counties (Hulse et al. 2001). It is, therefore, likely that this species occurs at VAFO, although probably at a relatively low density.

Southern (Coastal Plain) Leopard Frog (*Rana sphenocephala utricularia*) - Probable Nonresident

This species was put on the predicted list (Table 1) due to reliable records from Chester, Delaware, and Philadelphia Counties (Hulse et al. 2001). However, this species has not been found at VAFO by other investigators, has not been reported on VAFO WOCs, and VAFO is just outside the geographic range of this coastal plain inhabitant (Hulse et al. 2001). Accordingly, this species was likely never a resident of the park.

Upland Chorus Frog (*Pseudacris triseriata feriarum*) - Indeterminate

This species has not been found in the park by other investigators, has not been reported on WOCs, and was not detected by any of the searches used in this inventory. However, the status of this subspecies remains indeterminate, because there are reliable records from Chester and Montgomery Counties, VAFO is well within the geographic range of this animal (Hulse et al. 2001), and the park appears to have ample suitable habitat in the form of dense vegetation in woods, marshes, and meadows (Shaffer 1991; Hulse et al. 2001).

Turtles (order Testudines)

Bog Turtle (*Clemmys muhlenbergii*) - Probable Nonresident

This Federally threatened and Pennsylvania endangered species (Wild Resource Conservation Fund 1995) was put on the predicted list (Table 1) due to numerous recent and historical records from Chester, Montgomery, and Berks Counties (Wild Resource Conservation Fund 1995, Hulse et al. 2001). However, no investigators have found this turtle at VAFO, there have been no WOCs submitted, and in 1986 The Nature Conservancy conducted a survey and found no suitable habitat in the VAFO area (Anthony Davis, personal communication). Accordingly, it is very unlikely that the species occurs at VAFO.

Eastern Mud Turtle (*Kinosternum subrubrum subrubrum*) - Possible Extirpated Resident

This reptile has not been found in the park by other investigators, has not been reported on VAFO WOCs, and was not detected by any of the searches in this inventory. Recently removed from the list of endangered species in Pennsylvania, it is believed to be extirpated from the state (Shaffer 1991). The former range of this species included parts of Delaware and Chester Counties, but habitat loss has been attributed to the disappearance of this turtle from the state.

Red-bellied Turtle (*Pseudemys rubriventris*) - Possible Current Resident

This Pennsylvania threatened species (Wild Resource Conservation Fund 1995) was recorded at VAFO nearly twenty years ago (Cypher et al. 1985b). Since that time, there have been no sightings of this rare species, despite a special survey in 1994 by The Nature Conservancy to follow up on the Cypher et al. (1985b) report (Anthony Davis, personal communication), the surveys of Yahner et al. (1999), and the current inventory. The 1985 report placed the species in the desilting basin vernal ponds currently numbered as sites 22.05 and 22.07. These vernal ponds were subjected to basking turtle surveys, aquatic trapping, and general herpetological collecting, which detected many other large turtle species but no red-bellied turtles. However, this species is abundant and apparently reproducing in the canals of Phoenixville, where a wide range of size classes has been observed (H. Tiebout, personal observation). These canals are only 10-30 m from the Schuylkill River, from which they are separated by a low dike. This section of the river is only about 7 km upstream from VAFO. Accordingly, it is likely that the 1985 report is valid, and that this species may periodically inhabit VAFO, especially during years when the desilting basins retain large amounts of water during the warmer months.

Spotted Turtle (*Clemmys gutatta*) - Possible Current Resident

This little-known aquatic reptile has been reported on VAFO WOCs but was not detected in the current inventory. VAFO is well within the current range for this species (Hulse et al. 2001) and appears to contain ample suitable habitat in the form of wet meadows, swamps, and streams (Hulse et al. 2001). It is likely that this small turtle still inhabits VAFO or may periodically recolonize VAFO during wetter years when the wetlands (especially the desilting basins) retain water for most of the activity season.

Wood Turtle (*Clemmys insculpta*) - Possible Extirpated Resident

This mid-sized semiaquatic turtle has never been reported at VAFO, although the park lies well within its current range, which includes recent reliable sightings in Chester and Montgomery Counties (Hulse et al. 2001). This reptile is especially prone to over-collecting for personal ownership and for the commercial pet trade, as well as to population decline due to mortality on roadways (Hulse et al. 2001). It is likely that this habitat generalist (Hulse et al. 2001) was historically a resident at VAFO but has been over-collected due to high visitation rates within the park and subjected to high rates of road kill due to high commuter traffic through the park.

Lizards (order Squamata, suborder Lacertilia)

Broadhead Skink (*Eumeces laticeps*) - Probable Nonresident

This rare lizard, listed as a candidate species by the state (Shaffer 1991), was included in the predicted list (Table 1) due to an historical record from Chester County, about 30 km SW of VAFO (Hulse et al. 2001). Southeastern Pennsylvania lies at the extreme northern limit of the range of this skink, and this reptile has probably never been common in the state. The only recent record was in York County along the Susquehanna River. It is unknown whether this species ever dispersed as far north as VAFO, but there have been no records of any sort of its occurrence in the park. Accordingly, it almost certainly does not currently occur in the park.

Five-lined Skink (*Eumeces fasciatus*) - Possible Extirpated Resident

This lizard has never been recorded at VAFO, yet the species is widely distributed throughout the lower two-thirds of the state (Shaffer 1991). Because VAFO contains an abundance of suitable habitat, including fallen logs, rocks, and debris from abandoned human habitations (Hulse et al. 2001), it is likely the species once occurred in the park. Because there have been no reports of any lizards at VAFO, it is unlikely that this species currently inhabits the park.

Northern Fence Lizard (*Sceloporus undulatus hyacinthinus*) - Possible Extirpated Resident

As with the other two species of lizards, this small reptile has never been reported at VAFO. However, VAFO lies well inside the current geographic range of this species and appears to provide ample habitat containing open woodland, rocky outcrops, and fallen snags (Hulse et al. 2001). Thus, it is likely that this species once inhabited VAFO but currently no longer inhabits the park.

Snakes (order Squamata, suborder Serpentes)

Black Rat Snake (*Elaphe obsoleta obsoleta*) - Possible Current Resident

This large snake was reported at VAFO once during a survey in 1985 (Cypher et al. 1985b). Often relatively abundant where it occurs (Palmer and Braswell 1995), the range of this species includes the entire state, with reliable records from Chester and Montgomery Counties (Hulse et al. 2001). Nevertheless, after two years of field work, which included numerous planned general

herpetological collecting attempts to document this habitat generalist (Hulse et al. 2001; Shaffer 1991), none was found during the current inventory. Occasional anecdotal reports of this species did occur during the inventory, but it may be likely that the northern black racer was mistaken for the black rat snake, which it closely resembles. The black rat snake is primarily an upland species preferring the ecotone between forest and field (Hulse et al. 2001). It should therefore likely be present at VAFO, with its mosaic of upland hardwood forest and tall grass meadows. Accordingly, it is possibly present in the park at low density, with numbers potentially reduced due to high visitor density (these snakes are considered excellent pets [Smith 1961]) and the practice of mowing the ecotone between forest and meadow.

Eastern Hognose Snake (*Heterodon platirhinos*) - Indeterminate

This elusive, fossorial species (Hulse et al. 2001) has no written record as occurring within the park. However, VAFO does lie well within this species geographic distribution, which includes reliable records from Chester and Montgomery Counties (Hulse et al. 2001). In addition, the park contains a small amount of potentially suitable habitat (sandy areas, such as sandy banks along the Schuylkill River) and an abundance of potential prey (especially toads). About 5-10 years ago, one was reportedly found near the Train Station at Washington's Quarters and released along Valley Creek (B. Lambert, pers. comm.) Accordingly, this species remains indeterminate in status - it may have occurred historically in the park and cannot be ruled out as a possible current resident at low density.

Eastern Ribbon Snake (*Thamnophis sauritus sauritus*) - Indeterminate

This snake has never been reported at VAFO. However, the park contains abundant suitable habitat (rocky hillsides, grassy fields, forests, wetlands), which must be near permanent water (Hulse et al. 2001). In addition, the park is well within the range of this semi-aquatic, semi-arboreal reptile, and there are recent, reliable records from Montgomery County near VAFO (Hulse et al. 2001). Accordingly, this status of this species remains indeterminate.

Eastern Earth Snake (*Virginia valeriae valeriae*) - Possible Extirpated Resident

This species was put on the predicted list (Table 1) due to historical records from Montgomery and Berks Counties, but these populations in southeastern Pennsylvania are now believed to have been extirpated due to development (Hulse et al. 2001). VAFO is situated within or near to the former geographic range for this species (Hulse et al. 2001, but see Shaffer 1991 for a different range), and the park appears to have suitable habitat for this inhabitant of deciduous forest, which is often found under surface debris after heavy rains (Hulse et al. 2001). Although there are no records of this highly secretive snake (Shaffer 1991) occurring at VAFO, based on the fate of other local populations, this species should be considered a possible extirpated resident.

Eastern Worm Snake (*Carphophis amoenus amoenus*) - Possible Current Resident

Although this secretive, fossorial snake (Hulse et al. 2001) has not been reported at VAFO, the park contains an abundance of its preferred forested habitat and is well within the current geographic range of this species (Shaffer 1991; Hulse et al. 2001). Because this animal spends so

much of its life underground and is seldom found in the open, detection of this reptile can be very difficult (Hulse et al. 2001). Accordingly, it is possible this unobtrusive snake is currently a resident in the park but escaping detection.

Northern Redbelly Snake (*Storeria occipitomaculata occipitomaculata*) - Indeterminate

After a single unconfirmed sighting by a visitor near the VAFO Visitor Center lower parking lot (May 10, 2000; Bill Moses pers. comm. to Brian Lambert), a very complete search of the immediate area failed to detect this species. However, much of the habitat nearest the unconfirmed sighting was off-limits to inventory personnel due to asbestos contamination. Therefore, a more thorough search of the asbestos release site is needed to follow up this report. Accordingly, this species remains indeterminate in status. Originally put on the predicted list (Table 1) because VAFO appeared to fall within its geographic range (Shaffer 1991), a more recent range map indicates that this species has not historically been found in Chester or Montgomery Counties, although an old record from Philadelphia County does exist (Hulse et al. 2001).

Rough Green Snake (*Opheodrys aestivus*) - Probable Nonresident

This species was put on the predicted list (Table 1) based on the range map in Shaffer (1991). However, a more recent range map (Hulse et al. 2001) presents only a single reliable record from southeastern Pennsylvania. This record was from the extreme southwestern tip of Chester County, suggesting that VAFO is actually outside of the current range for this snake. In addition, VAFO has no record of this rare species, which is listed as threatened by the Commonwealth (Wild Resource Conservation Fund 1995). It should therefore be considered a nonresident of the park.

Future Inventory and Monitoring Recommendations

Additional Inventory Needed

This current inventory identified six species as "possible current residents," i.e., not detected by the inventory but with enough other evidence to suggest they might inhabit the park. Thus, the current inventory detected 29 out of 35 species, or about 83% of the likely resident species. Additional inventory efforts should be targeted specifically towards confirming these species as actual park residents. One of these species in particular, the red-bellied turtle, is listed as threatened by the Commonwealth and thus should receive special efforts to resolve its status.

Long-term Monitoring Program

Following the guidelines provided by Seigel and Simons (1995), it is recommended that two groups of species be considered for monitoring in National Parks: (a) common species (ecologically significant and yield statistically meaningful abundance data), and (b) species of special concern (because resource managers are mandated to evaluate and protect these populations).

Common species

It is recommended that the park monitor its amphibian species using the guidelines established by the federal government for three new monitoring programs that closely resemble three of the survey methods used in the current inventory. These are the Terrestrial Salamander Monitoring Program (TSMP, [http://www.mp1-pwrc.usgs.gov/sally/], for plethodontid salamanders), FrogWatch USA (http://www.nwf.org/keepthewildalive/frogwatch-app/index.htm, for all anurans), and the Amphibian Research and Monitoring Initiative (ARMI [http://wwwrcolka.cr.usgs.gov/armi/], for streamside salamanders). In addition, an extended TSMP survey method, which uses coverboards in all available terrestrial habitat types, should be used to survey for species in addition to the plethodontids. These four methods combined could potentially monitor 21 of the 29 herpetofauna species at VAFO (Table 12).

The standard TSMP coverboard surveys should be conducted every year, with three survey dates timed to coincide with the fall peak in plethodontid abundance, and another three survey dates timed to the spring peak. See Carfioli (1998, 2000) and Carfioli et al. (2000) for the best times to detect terrestrial salamanders. The TSMP methods should be extended to enable monitoring other common terrestrial reptiles and amphibians as well (Table 12). For example, coverboards could be deployed in habitats other than forest (e.g., tall grass meadows, wetland areas) and monitored outside of the peak salamander dates (e.g., include drier, warmer periods).

The FrogWatch USA anura calling surveys require no establishment of transects or traps, are inexpensive in terms of equipment and supplies, and are relatively efficient in terms of species detected per person-hour of sampling effort (Table 10). These surveys should be conducted annually, with 3-6 surveys done per year.

Table 12. Species at Valley Forge National Historical Park detected by five survey methods. The standard Terrestrial Salamander Monitoring Program (TSMP) includes only salamanders found under coverboards in forest habitat types. The extended TSMP includes all species found under coverboards in all habitat types. FrogWatch USA includes all anurans detected during anura calling surveys. The Amphibian Research and Monitoring Initiative (ARMI) includes all streamside salamander species found during natural substrate surveys in runs. The basking turtle survey (BTS) includes all species found using BTS.

Group	Common Name	TSMP	Ext. TSMP	FrogWatch	ARMI	BTS
Salamanders						
	Eastern (Red-spotted) Newt	X	X			
	Longtail Salamander				X	
	Northern Dusky Salamander				X	
	Northern Red Salamander	X	X		X	
	Northern Two-lined Salamander	X	X		X	
	Red-backed Salamander	X	X		X	
	Slimy Salamander	X	X			
Toads and Frogs						
	Bullfrog			X		X
	Eastern American Toad		X	X		
	Eastern Gray Treefrog		X	X		X
	Fowler's Toad			X		
	Northern Green Frog			X		
	Northern Spring Peeper			X		
	Pickerel Frog		X	X		X
	Wood Frog			X		
Turtles						
	Common Map Turtle					X
	Common Musk Turtle					X
	Common Snapping Turtle					X
	Eastern Painted Turtle					X
	Red-eared Slider					X
Snakes						
	Common Garter Snake		X			X
	Eastern Milk Snake		X			
	Eastern Ribbon Snake					
	Northern Black Racer		X			X
	Northern Brown Snake		X			
	Northern Copperhead		X			
	Northern Ringneck Snake		X			
	Northern Water Snake					X
	Queen Snake					X

The ARMI streamside salamander surveys require establishing marked transects and are more labor-intensive than the FrogWatch surveys. It is recommended that permanently marked transects be established along the four runs surveyed in the current inventory, to be surveyed in the spring and summer at three-year intervals. This regimen is subject to change pending recommendations generated by on-going ARMI research.

Species of special concern

No species listed at the state or federal level were detected by the current inventory. However, eight such species are on the predicted list (Table 1), and if they are detected by future inventory or monitoring efforts, then long-term monitoring of their populations should be undertaken.

Though not a listed species in Pennsylvania, the queen snake merits additional, long-term monitoring due to concern over the future of this sensitive aquatic reptile (Hulse et al. 2001). This snake is currently listed as endangered by the states of New York and Wisconsin, and at the national level in Canada. According to Hulse et al. (2001), in Pennsylvania this species may be suffering local extirpations due to the negative impacts of water pollution on crayfish, its primary prey. These authors state that "…careful monitoring of queen snake populations is severely needed to determine if they should be placed in a protected category." Because this snake has already been extirpated from many parts of Bucks, Delaware, and Philadelphia Counties (Hulse et al. 2001), the population persisting at VAFO assumes regional significance. This species should be monitored with three spring and three fall basking turtle surveys along Valley Creek each year, which could potentially help monitor an additional 11 species (Table 12). These surveys, combined with the monitoring of common species described above, could potentially monitor 28 of the 29 herpetofauna species in the park, while requiring considerably fewer resources than the current inventory.

Management Recommendations

This inventory has demonstrated that VAFO currently supports a fairly diverse herpetofauna community, including some species not commonly found elsewhere in the region (e.g., common map turtle). Several new management policies or programs could help maintain or enhance the biodiversity of herpetofauna in the park. By following these recommendations, VAFO should be able to maintain its current resident species well into the future, with the additional possibility of restoring some of its historical species that have been locally extirpated.

Maintaining Current Resident Species

Rare or restricted species

Some resident species are extremely rare and/or appear limited to a very restricted geographic range within the park. These attributes make these species especially vulnerable to local extinction, a process that has probably already resulted in the extirpation of some former resident amphibians and reptiles. The inventory has identified eight such species: eastern newt, slimy salamander, wood frog, Fowler's toad, common musk turtle, common map turtle, northern brown snake, and eastern milk snake. As described in the following paragraphs, seven of these species might benefit from specific management activities.

The two salamanders had very few individuals and were limited to very restricted ranges. The eastern newt appears dependent on the desilting basins, the protection of which is discussed under "General habitat enhancement" below. The slimy salamander was encountered only once, under a coverboard on Mount Misery. This species is most abundant in mature deciduous forest, in part because it has direct development (no aquatic larval stage) and is dependent upon large rotting logs for the deposition of eggs (Hulse et al. 2001). Log size is very important because large logs retain moisture better than small logs and hence provide better conditions for developing embryos. VAFO does have an abundance of rotting logs in many of its forested hillside areas, due to the thousands of trees that were killed in the 1980's by gypsy moths (B. Lambert, pers. comm.). However, most of these rotting logs are of relatively small diameter compared to what would be found in a truly mature forest. Nevertheless, as the VAFO forest continues to mature and the largest trees begin to die, it is likely that the abundance of suitable oviposition sites will increase and this species should increase in density. Accordingly, no special management activities are recommended for this species other than preserving the oldest tracts of deciduous forest in the park.

The two anurans also appear to have a precarious existence at VAFO. In the case of the wood frog, VAFO appears to contain ample adult habitat (primarily lowland forest [Hulse et al. 2001]), but may lack enough suitable breeding sites. Wood frogs usually breed in a variety of permanent and temporary bodies of water that are free of vertebrate predators (Hulse et al. 2001). However, the two wetland sites with calling wood frogs were very near the river and apparently are easily colonized by a variety of turtles during wet periods. Site 22 was used for basking turtle surveys and found to contain three turtle species (eastern painted turtle, common snapping turtle, and red-eared slider), all known to consume aquatic animals (Vogt 1981; Palmer and Braswell 1995; Hulse et al. 2001) and hence capable of preying on wood frogs and their larvae. Site 25 was

never covered by basking turtle surveys but may also have contained vertebrate predators. The wood frog might benefit from the enhancement (deepening and/or enlarging) of several existing vernal pools that are too small and too distant from the river to attract turtles. These pools are located just north of the embankment that runs along the north side of the gravel road north of Boy Scout Field.

In the case of Fowler's toad, VAFO may be lacking in adult habitat (usually open sandy or gravelly areas near streams or rivers [Hulse et al. 2001]) and possibly in breeding sites (ponds near streams and rivers). One adult Fowler's toad was found on a gravel road, but the others were found along the river, where a group of 15 was found together at a single sandy bank. Other than these two types of sites, the park has very few areas with sandy or gravelly soils. It is possible that the historical diking and dredging of the river to remove coal silt have reduced the availability of sand and gravel deposits typical of rivers that periodically flood their banks into an adjacent flood plain. The observation that males called from the river but were not detected in the adjacent desilting basins, suggests that they may be attempting to reproduce in the river near the only open sandy areas in the park. One possible habitat enhancement that might benefit this toad would be the addition of some sandy/gravelly substrates near the river and desilting basins (see details under "General habitat enhancement" below).

The two turtle species were each detected only twice during the inventory and found only in the Schuylkill River. Two habitat features known to limit turtle density, suitable structure in the river for basking (McCoy and Lovich 1993) and sandy or gravelly substrate for egg deposition, are both in short supply in the vicinity of the river. Methods to enhance both features, as presented below under "General habitat enhancement," would likely benefit both of these extremely rare chelonians.

The two snakes have each been found within an extremely small geographic area within the park. The northern brown snake has been found in one stretch of lowland forest and in part of an adjacent tall grass meadow. The milk snake has only been found under a few coverboards at a single meadow site. However, because this species uses a mix of habitats, including grasslands, ecotones (grassland/forest interface), and deciduous forest (Hulse et al. 2001), it likely also uses the adjacent upland forest on the south facing slope of Mount Misery. Thus, both species appear associated with the forest/meadow border, which may put them at particular risk when the meadow areas adjacent to forest are periodically mowed to maintain a firebreak. Keeping the meadow areas adjacent to forest at sites 12 and 13 unmowed during the warm months might prove beneficial to these two species.

General habitat protection and enhancement

Implementing the following recommendations should help VAFO provide high quality habitat capable of maintaining or increasing the species richness of its herpetofauna community.

1. Continue to preserve forested areas with the oldest trees. Certain species of reptiles and amphibians are dependent upon mature forest. Specific habitat features that favor these animals are the formation of a rich leaf litter layer and the accumulation of snags (standing dead trees) and coarse woody debris (fallen trunks and branches).

2. Allow natural structure to accumulate in lotic (flowing freshwater) systems. Aquatic and semi-aquatic reptiles and amphibians often require the basking sites and cover provided by fallen branches, trunks, and the debris dams these woody elements help form. At present, VAFO cannot allow woody debris to accumulate in the Valley Creek channel because it could exacerbate an already severe problem of bank erosion (B. Lambert, pers. comm.). Should the bank stabilization problem be rectified in the future, this recommendation might warrant consideration.

3. Provide turtle nesting sites that are safe from visitor and predator pressure. Almost all turtles require well-drained soils for oviposition sites. However, possibly because of unnatural hydrological regimes, VAFO has almost no natural sandy/gravelly soils in close proximity to its major turtle habitats (Valley Creek, Schuylkill River, and the desilting basins). Areas that are available for nesting, such as gravel pathways and coal silt deposits, probably do not provide ideal substrate for eggs and may be subject to heavy visitor pressure. Artificial nesting material (sand with fine gravel) could be provided in areas easily accessible to turtles but not heavily used by visitors. As an added precaution, these sites could be fenced during the egg-laying months (May - July) to reduce nest predation. The addition of nesting substrate might also benefit other species known to favor well-drained soils, such as the eastern spadefoot toad, Fowler's toad, and eastern hognose snake.

4. Control the invasive non-native Japanese stilt grass (*Microstegium vimineum*), especially around the scree slopes of Mounts Misery and Joy. This exotic plant is covering some of the rocky slopes on Mount Misery that are basking and potential hibernating sites for several snake species. Extensive plant coverage could change the insolation and thermal regimes of these sites, rendering them unsuitable for these reptiles. VAFO currently does not attempt to control this plant, due to the excessive amount of herbicide needed to suppress it (B. Lambert, pers. comm.). If a non-toxic control method becomes available, the park might consider using it.

5. Enhance protection of the wetland/lowland forest habitat complex north of the river (referred to as the herpetofauna hot spot, see "Species Richness by Habitat Type" above) from excessive unauthorized visitor pressure. In particular, this part at VAFO is subject to considerable off-trail mountain biking, and in drier years the desilting basins can sustain marked damage to the benthic zone (K. Heister, pers. comm.).

6. Increase efforts to educate visitors about park regulations that protect its natural resources. On numerous occasions visitors were observed attempting to remove plants, animals, and other natural objects from the park, so the Law Enforcement Park Rangers were notified. This practice may be common, in part because people are unaware that all natural resources are protected. Visitor education programs, inclusion of the regulations in the VAFO Official Map and Guide, and better signage might help reduce this problem.

<u>Restoration of Extirpated Species</u>

The National Park Service has stated its intention to restore native animals that have been extirpated from its parks (NPS 2000). To the extent that VAFO management desires to pursue this intent, this inventory has identified nine species as possible extirpated residents. Of these

species, one reptile species appears to be the most suitable candidate for a future reintroduction program - the northern fence lizard. The reason this species became locally extirpated is unknown, but the cause may date back to the loss of forested habitat during the encampment of Washington and his troops (Lundgren et al. 2002). However, as previously discussed (see "Species on the Predicted List Not Detected" above), the park now contains ample suitable habitat. This species is locally abundant where it occurs and hence ecologically significant, making it an important element to be restored to the VAFO herpetofauna community. On a more practical level, because it occupies relatively open habitats and tends to bask in conspicuous areas on elevated logs and trunks, this lizard would be relatively easy to monitor with visual surveys. In addition, subadults and adults are large enough to mark with PIT tags (Germano and Williams 1993), so that individual identity could be easily determined. This would allow detailed analyses of population growth, home range size, microhabitat use, and other parameters necessary to evaluate the restoration project.

A second reptile, the black rat snake, is now designated as a possible current resident pending additional inventory work. Should future research determine that it is a possible extirpated resident, it would make a suitable candidate for restoration for the same reasons as for the northern fence lizard. Although the reason for extirpation will likely never be known, VAFO currently contains ample suitable habitat for this species (see "Species on the Predicted List Not Detected" above). In addition to being able to accommodate PIT tags, subadults and adults are also large enough for radio telemetry devices to help evaluate the restoration effort.

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Appendix - Glossary of Terms and Acronyms

ACS Anura Calling Survey

anthropogenic habitat types road (paved or unpaved), railroad bed, and developed (inside buildings or on adjacent grounds). For convenience, the former group of seven habitat types is referred to as natural, the latter group of three as anthropogenic.

ARMI Amphibian Research and Monitoring Initiative, USGS

AT Aquatic Trapping

BTS Basking Turtle Survey

CB Coverboard

CRK Valley Creek habitat type

DF Drift Fence

encounter an animal detected during a survey. Because animals were not individually marked (except eastern box turtles), an encounter is not the same as an individual animal (i.e., multiple detections of the same animal at different times were recorded as multiple encounters).

GHC General Herpetological Collecting

GPS global positioning system

habitat general description of landscape features typical of where a species occurs; not the same as habitat type

habitat type one of 10 categories of habitat used in the inventory, listed under anthropogenic habitat types and natural habitat types

HDI Habitat Diversity Index = $H' = - \Sigma \text{Log}_{10}(p_i)*(p_i)$

where p_i = the proportion of total sightings for a given species that occurred in habitat type i

LF lowland forest (< 61 m elevation) habitat type

little-known species herpetofauna species that had previously been reported in one or two of the five studies presented in Table 1

NAAMP North American Amphibian Monitoring Program, USGS

natural habitat types upland forest (above 61 m [200'] elevation), lowland forest (below 61 m [200'] elevation), tall grass meadows (only mowed once per year), lentic systems (wetlands, ponds, and vernal pools), and three distinct lotic systems (runs [small streams], Valley Creek, and the Schuylkill River).

NPS National Park Service

NSSF Natural Substrate Survey in Forest

NSSR Natural Substrate Survey in Runs

observation any datum recorded is considered an observation (e.g., SVL for a particular salamander)

PS Project Statement from a VAFO resource management plan

PSU Pennsylvania State University

RIV Schuylkill River habitat type

RUN run (small stream) habitat type

sampling site one of 55 standard sites used for repeated sampling

survey a single sampling event for a given survey method (e.g., checking all coverboards constituted one coverboard survey)

SVL snout-vent length

TGM tall grass meadow habitat type

TSMP Terrestrial Salamander Monitoring Program, USGS

UF upland forest (> 61 m elevation) habitat type

USGS United States Geological Survey

UTM universal transverse mercator map projection for GIS

VAFO Valley Forge National Historical Park

WCU West Chester University, West Chester, PA

WET wetland habitat type

WOCs Wildlife Observation Cards, reported in Yahner et al. (1999)

well-known species herpetofauna species that had previously been reported in three or more of the five studies presented Table 1